United States
Environmental Protection
Agency

Office of Water
(WH-586)
Washington, DC 20460

EPA-440/5-91-003
July 1991

EPA

Biological Criteria

State Development And Implementation Efforts

Printed on Recycled Paper

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U.S. Environmental Protection Agency

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Acknowledgements

The U.S. Environmental Protection Agency's Office of Water sponsored development of this document through U.S. EPA Contract No. 68-03-3533 to Dynamac Corporation. Suzanne Marcy and George Gibson of the Office of Water managed document development, and Mark Southerland of the Dynamac Corporation served as technical editor.

This document is essentially a compilation of State experiences with biological criteria. Therefore, EPA is especially indebted to the officials who contributed information on their water quality programs, helped in the review process, and offered to further share their expertise with readers of this report. We wish to thank Patricia Bailey, John Bender, Mark Blosser, Bob Bode, Dave Courtemanch, Susan Davies, Steve Fiske, John Geise, Guy Hoffman, Jim Hulbert, Roy Keinsasser, Richard Langdon, John Maxted, Jimmie Overton, Dave Penrose, Ernest Pizzuto, Steve Tidwell, and Chris Yoder. We especially wish to acknowledge Dave Penrose for his expertise and efforts in the preparation of this report while he was temporarily assigned to the EPA.

Definitions

To protect water quality, States must adopt and apply water quality standards that incorporate a designated use for the body of water, criteria that describe conditions the waterbody must attain to meet that use, and an antidegradation policy. When developing biological criteria to protect a designated aquatic life use, States need to understand the concepts and techniques of ambient biological assessment, primarily those applicable to the selection of target groups within aquatic communities and the definition of biological integrity by which to measure the condition of the biota. To this end, readers should consider the following definitions, which provide a standard frame of reference for the concepts discussed in this document.

- ❑ An AQUATIC COMMUNITY is an association of interacting populations of aquatic organisms in a given waterbody or habitat.
- ❑ A BIOASSAY is a toxicity test that uses selected organisms to determine the acute or chronic effects of a chemical pollutant or whole effluent.
- ❑ A BIOLOGICAL ASSESSMENT is an evaluation of the biological condition of a waterbody that uses biological surveys and other direct measurements of resident biota in surface waters.
- ❑ BIOLOGICAL CRITERIA, or biocriteria, are numeric values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting waters that have been given a designated aquatic life use.
- ❑ BIOLOGICAL INTEGRITY is functionally defined as the condition of the aquatic community inhabiting unimpaired waterbodies of a specified habitat as measured by community structure and function.
- ❑ BIOLOGICAL MONITORING is the use of a biological entity as a detector and its response as a measure to determine environmental conditions. Toxicity tests and biological surveys are common biomonitoring methods.
- ❑ A BIOLOGICAL STANDARD is a legally established State rule that includes a designated biological use (goal) and biological criteria.
- ❑ A BIOLOGICAL SURVEY, or biosurvey, consists of collecting, processing, and analyzing representative portions of a resident aquatic community to determine the community structure and function.
- ❑ An ECOREGION is a relatively homogeneous area defined by similarity of vegetation, hydrology, and land use. Ecoregions help define designated use classifications of specific waterbodies.
- ❑ DESIGNATED USES are specified in water quality standards for each waterbody or segment, whether or not they are being attained.
- ❑ An IMPACT is a change in the chemical, physical, or biological quality or condition of a waterbody that is caused by external sources.
- ❑ An IMPAIRMENT is a detrimental effect on the biological integrity of a waterbody caused by an impact that prevents attainment of the designated use.

Executive Summary

States are showing increasing interest in developing biological criteria as part of their water quality programs. Some have already instituted biological criteria to support their State standards. To encourage adoption of biological criteria throughout the country, the U. S. Environmental Protection Agency (EPA) is providing both program and technical guidance for the development and implementation of State programs.

This document presents the most recent review of biological criteria development in each of the 50 States (plus the District of Columbia, Puerto Rico, and the Virgin Islands). Most States (39) conduct special site studies to assess the impacts of specific point and/or nonpoint sources of pollution. However, use of the results has been limited to defining regional reference conditions or to establishing biological criteria. Fewer States (31) are conducting biological network trend monitoring, in which data are used to define regional reference conditions and establish the foundation of biological criteria. Most of these State programs are hampered by constraints on staffing and funding.

A total of 31 State biomonitoring organizations are actively involved in the research, development, or implementation of biological criteria. The level of participation ranges from the 17 States that are conducting biological investigations aimed at assessing biological criteria (but are not actively developing criteria), to the five States that are currently developing biological criteria, to the eight State organizations that are using narrative or numeric biological criteria in support of their water quality regulations. Several other States are designing monitoring surveys to assess the effectiveness of ecoregional reference conditions.

This document includes five case studies on States with the most active biological criteria programs—Ohio, Maine, North Carolina, Florida, and Arkansas—and seven case summaries on States with substantial experience in biological criteria—Texas, Connecticut, Vermont, New York, Nebraska, Delaware, and Minnesota.

Ohio's experience with biological criteria has demonstrated that an effective program can be cost effective, compared with traditional approaches, and needs only representative, not exhaustive, samples of aquatic biota. In Ohio and North Carolina, biological assessments have uncovered previously unidentified water quality impairments or revealed problems before they became severe. Maine recommends adoption of explicit standards to give a statutory basis for enforcement and management efforts that are aimed at aquatic life. Court decisions in Ohio and Florida have upheld the validity of biological criteria for determining nonattainment of water quality standards. Arkansas' experience illustrates the usefulness of ecoregional biological criteria in setting standards that are realistically attainable and ecologically relevant.

Foreword

In 1987, EPA's Office of Water published a report, *Surface Water Monitoring: A Framework for Change,* that strongly recommended expanded use of biomonitoring in water quality programs. In December 1987, the National Workshop on Instream Biological Monitoring and Criteria recommended that "the concept of biocriteria and the information generated by ambient biological sampling should be integrated into the full spectrum of State and Federal surface water programs."

Biological Criteria: State Development and Implementation Efforts is one of a series of three reports prepared by the Office of Water and its contractors to provide guidance to States as they develop biological criteria. This report supplements EPA's other biological criteria guidance documents, with practical examples that show how States are currently developing and using the criteria. It also serves as a status report on efforts throughout the 50 States to establish biological criteria.

Chapter 1

Introduction

This document is designed to be a valuable resource for States that are planning or developing biological criteria programs. It supplements EPA's program guidance with case histories about existing State programs and reviews State efforts to develop biological criteria.

Key concepts relating to biological criteria are provided in Definitions. These terms, which are common to all EPA guidance documents for biological criteria, have been used to provide consistency in the discussion of State programs. Chapter 2 of this report describes current biological criteria efforts in the 50 States. Detailed case studies of five States that have intensive biological criteria programs are included in Chapter 3, and case summaries of seven additional State efforts to develop biological criteria are presented in Chapter 4.

Overview of Biocriteria Development

Biological criteria are narrative expressions that may be accompanied by numeric values describing the biological integrity of aquatic communities inhabiting waters that have a given aquatic life use. As such, they directly address the objective under section 101 of the Clean Water Act: to restore and maintain the biological integrity of the Nation's waters.

Biological criteria supplement rather than replace current programs by providing a direct measure of aquatic communities at risk from human activities. Used together, chemical criteria, whole-effluent toxicity evaluations, and biological criteria provide a powerful, integrated, ecological approach to water quality evaluation.

In September 1987, EPA published a major management study entitled *Surface Water Monitoring: A Framework for Change* that strongly emphasized the need to "accelerate development and application of promising biological monitoring techniques" in State and EPA monitoring programs. In December 1987, the National Workshop on Instream Biological Monitoring and Criteria advocated the same measures but also stressed the importance of combining the new biological criteria and assessment methods with traditional chemical and physical procedures. Both recommendations were presented at the June 1988 National Symposium on Water Quality Assessment, where a work group of representatives from several State and Federal agencies unanimously agreed that a national bioassessment policy should be developed to both encourage the expanded use of the new biological tools and direct their rational implementation across the water quality programs. In April 1990, EPA's Office of Water Regulations and Standards issued a policy statement encouraging States to develop biological criteria and published *Biological Criteria: National Program Guidance for Surface Waters.* Another guidance document, *Biological Criteria: National Technical Guidance for Surface Waters,* is being developed.

Chapter 2

State Biological Criteria Development Programs

In developing biological criteria for water quality programs, States have used a wide range of efforts to improve biological assessment methods, transform biological monitoring programs into ones using biological criteria, and incorporate biological criteria into water quality standards. The legislative and administrative environments of State programs ultimately determine the most effective structure for particular biological criteria programs. This survey of State efforts in biological criteria development illustrates both the differences and the many similarities of existing and emerging programs.

Although most States conduct some kind of biological survey program, few have developed biological criteria. Biological survey programs vary, but they generally fall into two categories: network trend monitoring—systematic biological surveys conducted over set intervals, usually from fixed stations, and special site studies—biological surveys conducted at selected locations, usually to assess impacts from specific sources. However, State efforts to develop biological criteria are often unique to a particular area.

Table 1 (at the end of this chapter) lists the status of biological survey and biological criteria programs in the 50 States (plus the District of Columbia, Puerto Rico, and the Virgin Islands). Figures 1 and 2 illustrate the status of biological survey programs and biological criteria programs in each State.

Biological Surveys

All but four of the States (and Puerto Rico) conduct some form of biological survey program that includes either special site studies or network trend monitoring. Special site studies are biological surveys that are conducted at selected locations, usually to assess impacts from specific sources—including use attainment assessments by States and dischargers. In network trend monitoring, systematic biological surveys are collected over set intervals, usually from fixed stations. Fish and macroinvertebrates are commonly collected for both kinds of biological surveys; however, plankton, periphyton, and macrophytes are also

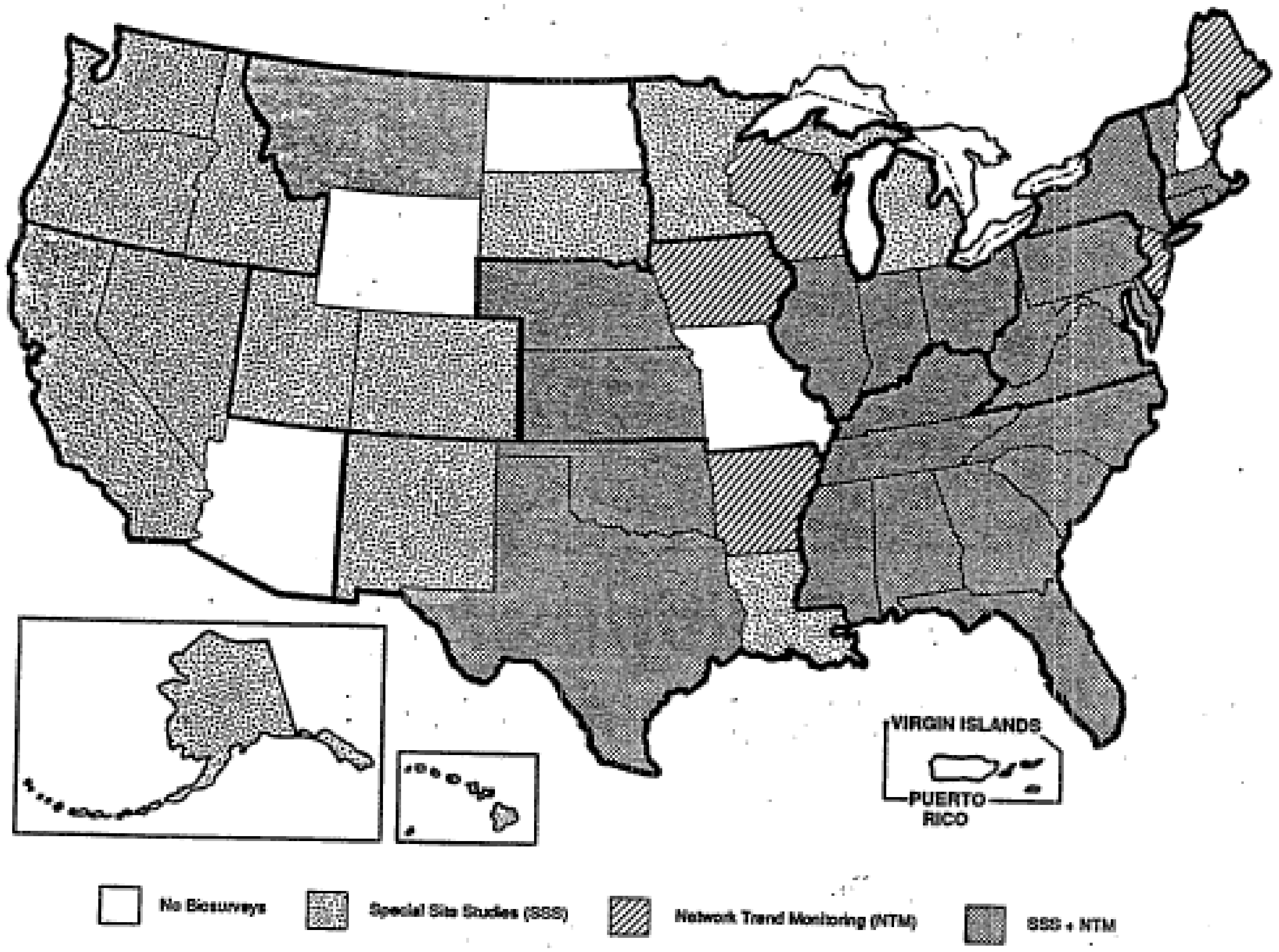


Figure 1.—Status of biological survey programs in the 50 States.

used in some States. Twenty-six States conduct both special site studies and network trend monitoring in their biological survey programs. Special site studies alone are performed in 13 States (and the Virgin Islands), and network trend monitoring alone is conducted in 5 States (and the District of Columbia).

Biological Criteria

Of 31 States currently involved in the research, development, or implementation of a biological criteria program, 17 are involved in some form of research or planning. Colorado, Kentucky, Illinois, and Tennessee use evaluative metrics to assess the resident biota. Massachusetts and Michigan are researching biological criteria, and Alabama, Arizona, Idaho, Iowa, Mississippi, and Montana are using ecoregions in their studies. Indiana, Kansas, Oregon, Virginia, and Wisconsin are already planning for biological criteria, while three States—Delaware, Minnesota, and Nebraska—are developing biological criteria programs.

New York is proposing the use of biological criteria for site-specific evaluations of water quality impairment. In Connecticut and Vermont, biological criteria are being used administratively to support water quality standards. Narrative biological criteria have been incorporated into water quality standards in Arkansas, Maine, Ohio, North Carolina, and Texas. Florida and Ohio have incorporated numeric biological criteria into their water quality standards.

Five States that use biological criteria to support water quality standards are discussed in Chapter 3. Three—Ohio, Maine, and North Carolina—are applying the biological criteria approach throughout their water quality standards programs to assess aquatic life use impairments and manage water quality impacts.

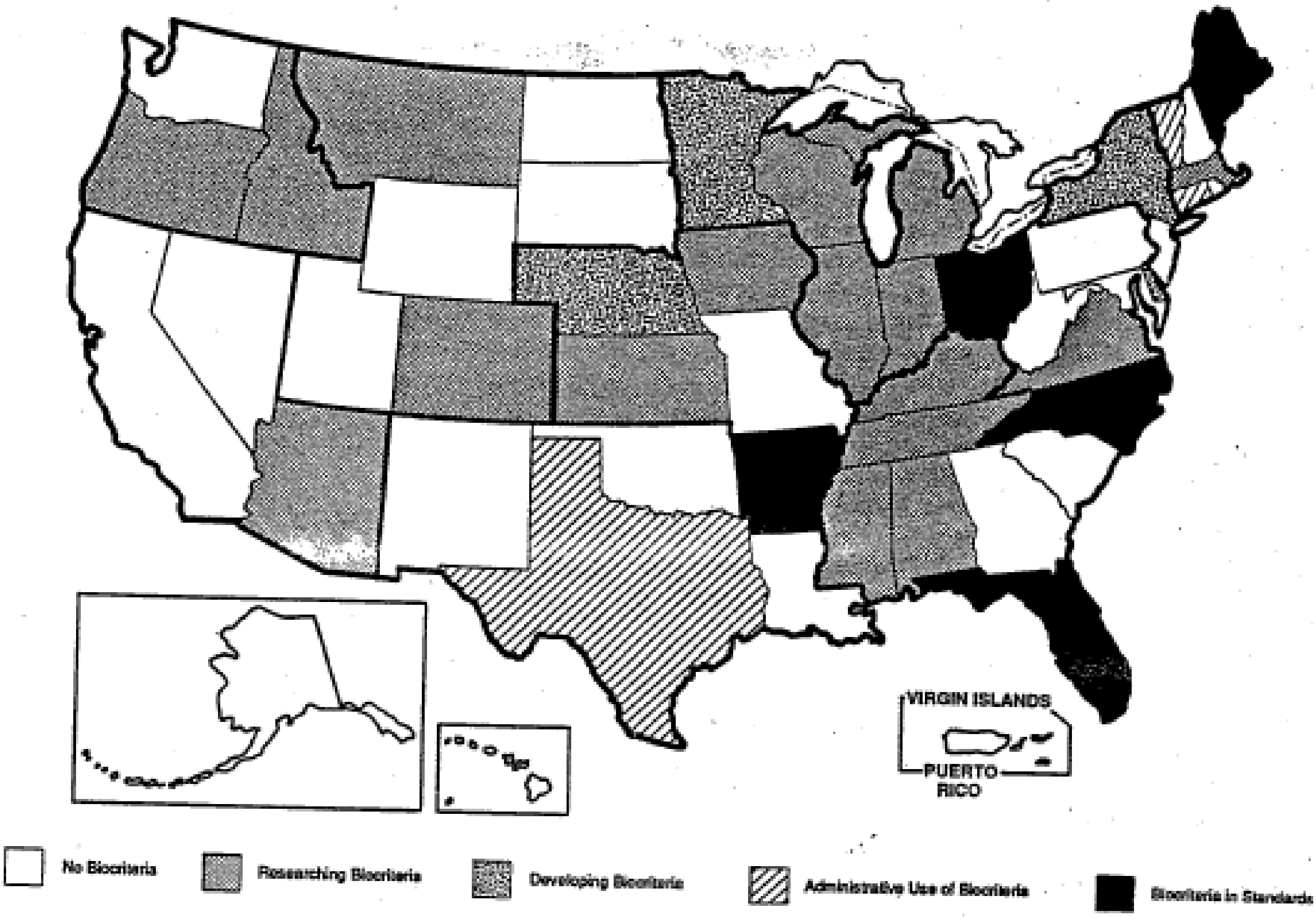


Figure 2.—Status of biological criteria programs in the 50 States.

Ohio has developed the most detailed use of biological criteria throughout different ecoregions and waterbody types. Use classifications based on biological criteria have been upheld in Ohio courts, and, in 1990, biological criteria were directly incorporated into that State's water quality standards. Maine has developed specific aquatic life use classifications in anticipation of incorporating criteria based on statewide macroinvertebrate sampling into its water quality standards. North Carolina uses biological criteria for different geographical regions to assess impairment of resident biota and identify waterbodies that are exceptional aquatic life sites.

Two other States also use biological criteria for specific objectives. Florida has a long-standing numeric criterion for freshwaters and a new standard for wetlands; both mandate specific levels of invertebrate species diversity. Arkansas has completed an ecoregion project that defines areas with naturally low dissolved oxygen. The State plans to develop different criteria for these regions.

Seven additional State programs currently developing biological criteria are summarized in Chapter 4. Texas, Connecticut, Vermont, New York, and Nebraska have adopted different methods for evaluating biological conditions in support of narrative standards. Minnesota and Delaware are just beginning to develop biological criteria programs.

States With Active Biological Criteria Programs

Five States are using biological criteria to define aquatic life use classifications and enforce water quality standards. Three—Ohio, Maine, and North Carolina—have made biological criteria an integral part of comprehensive water quality programs.

Ohio has instituted the most extensive use of biological criteria in defining use classifications and assessing water quality. The State used an ecoregional reference site approach to develop biological criteria for Ohio rivers and streams. Within each of the State's five ecoregions, criteria were derived for three biological indices (two for fish communities and one for macroinvertebrates). Ohio has used its biological criteria to demonstrate attainment of aquatic life uses and find previously unknown environmental degradation. Twice as many impaired waters were discovered by using biological criteria and chemistry assessments together than with chemistry assessments alone. Upgraded use designations based on biological criteria have been upheld in Ohio courts. In February 1990, Ohio EPA adopted numeric biological criteria for its water quality standards regulations.

Maine has enacted a revised water quality classification law specifically designed to facilitate use of biological assessments. Descriptions of each of the four water classes include aquatic life conditions necessary to attain that class. Maine is now developing a set of dichotomous keys to serve as biological criteria that are based on a statewide database of macroinvertebrate samples. The State's program will not play a significant role in permitting; however, it will be used to assess the degree of protection afforded by effluent limitations.

To assess impairments to aquatic life uses, North Carolina has developed biological criteria that are written as narratives in its water quality standards. Biological data and criteria are used extensively to identify waters of special concern or those with exceptional water quality. The State employs biological criteria to assess high quality waters (HQW), outstanding resource waters (ORW), and nutrient sensitive waters (NSW) that are at risk from eutrophication. Although the regulations do not stipulate specific biological measures, strengthened use of biological monitoring data to assess water quality is being proposed for incorporation into North Carolina's water quality standards.

Two additional States are using biological criteria for specific water quality problems in their streams and rivers. Florida has a biological criterion for invertebrates within its State standards: species diversity within a waterbody, as measured by the index, may not fall below 75 percent of reference measures. This criterion has been used in enforcement cases to obtain injunctions and monetary settlements.

Arkansas has rewritten aquatic life use classifications to reflect biological criteria developed for each of its ecoregions. Many Arkansas cities are designing wastewater treatment plants that meet the realistically attainable dissolved oxygen conditions determined by the new criteria.

States Developing Biological Criteria

Seven States are making limited use of biological criteria or are developing them for future applications.

- Texas has narrative biological criteria that describe aquatic life attributes on a sliding scale from limited to exceptional.
- Connecticut is developing qualitative bioassessment methods to complement narrative biological criteria for benthic macroinvertebrates.
- Vermont uses a set of administrative rules to support existing aquatic life narratives in its water quality standards.
- New York has developed numeric biological criteria to support enforcement actions and intends to incorporate these criteria into state water quality standards.
- Nebraska uses aquatic life bioassessments based on narrative biological criteria to support permit writing and pollution control.
- Delaware and Minnesota are in the early stages of developing reference conditions for biological criteria programs.

Table 1.—Biological criteria programs across the 50 States.

STATE	BIOLOGICAL SURVEYS	BIOLOGICAL CRITERIA
Alabama	Network Trend Monitoring Special Site Studies (fish, macroinvertebrates)	Conducting a cooperative ecoregion project with Mississippi that may be used to implement biocriteria.
Alaska	Special Site Studies	None
Arizona	None	Long-term research plan for applying ecoregions to water quality standards and biological criteria.
Arkansas	Network Trend Monitoring (macroinvertebrates, fish)	Completed ecoregion project with regional standards for fish, physical habitat, and water quality.
California	Special Site Studies (marine)	None
Colorado	Special Site Studies	Developed evaluative metrics for biota.
Connecticut	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	Informal biological criteria for benthic macroinvertebrates in place since 1987. Several ecoregional reference sites have been designated.
Delaware	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies	Biological criteria development under way with preliminary sampling and identification of possible reference sites.
District of Columbia	Network Trend Monitoring (macroinvertebrates, plankton)	None
Florida	Network Trend Monitoring (macroinvertebrates) Special Site Studies	Longstanding legal biological criterion based on macroinvertebrates diversity index.
Georgia	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	None
Hawaii	Special Site Studies (marine)	None
Idaho	Special Site Studies (macroinvertebrates)	Evaluating ecoregional reference sites in the Snake River catchment using rapid bioassessment techniques.
Illinois	Network Trend Monitoring (macroinvertebrates, fish) Special Site Studies (macroinvertebrates)	Using Index of Biotic Integrity (IBI) for basin survey and to assess use attainment for 305b reports.
Indiana	Network Trend Monitoring (phytoplankton, macroinvertebrates, fish) Special Site Studies (phytoplankton, macroinvertebrates, fish)	Planning for biocriteria development.
Iowa	Network Trend Monitoring	Conducting ecoregional sampling to classify streams.
Kansas	Network Trend Monitoring (macroinvertebrates) Special Site Studies (macroinvertebrates, fish, periphyton)	Considering fish community metric for existing water resource assessments.
Kentucky	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	Index of Biotic Integrity (IBI) is determined for all mine projects.
Louisiana	Special Site Studies (fish, macroinvertebrates)	None

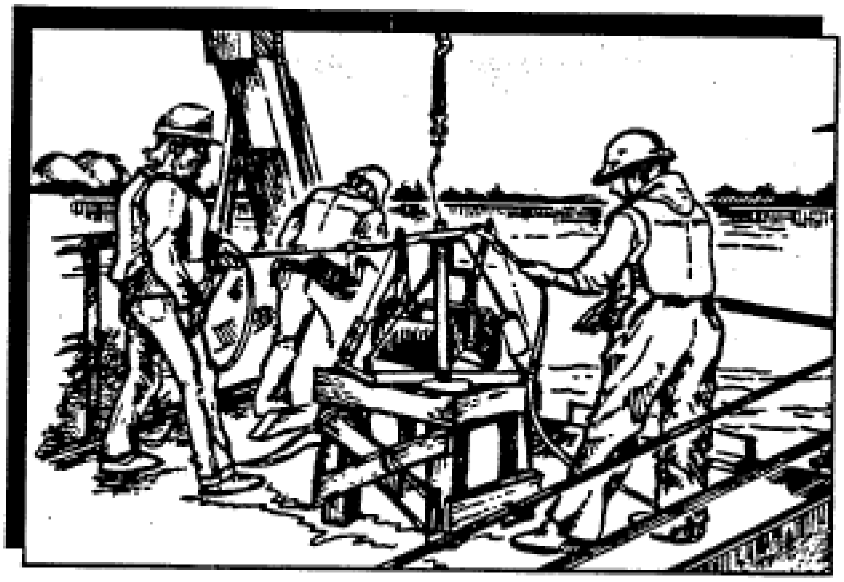
Table 1 (continued)

STATE	BIOLOGICAL SURVEYS	BIOLOGICAL CRITERIA
Maine	Network Trend Monitoring (macroinvertebrates)	Revised water quality standards to include narrative biological criteria based on decision matrix of ambient macroinvertebrates community data. Data are used to assess attainment of standards for designated uses.
Maryland	Network Trend Monitoring (macroinvertebrates) Special Site Studies (macroinvertebrates)	None
Massachusetts	Network Trend Monitoring (macroinvertebrates) Special Site Studies	Classified streams with extensive field data on fish species and habitats.
Michigan	Special Site Studies (fish, macroinvertebrates)	Evaluating biological criteria for Michigan.
Minnesota	Special Site Studies (fish, macroinvertebrates)	Developing regional fish community metrics.
Mississippi	Network Trend Monitoring (macroinvertebrates, fish) Special Site Studies (fish)	Conducting a cooperative ecoregion project with Alabama that may be used to implement biocriteria.
Montana	Network Trend Monitoring (macroinvertebrates) Special Site Studies (plankton, macroinvertebrates)	Conducting ecoregional sampling to classify streams.
Nebraska	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (macroinvertebrates)	Completed multiyear, statewide stream biosurvey aimed at establishing a standards framework with regional criteria, reference sites, and species lists.
Nevada	Special Site Studies (macroinvertebrates, periphyton)	None
New Hampshire	None	None
New Jersey	Network Trend Monitoring (fish, macroinvertebrates, periphyton)	None
New Mexico	Special Site Studies (macroinvertebrates)	None
New York	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (macroinvertebrates)	Proposing biocriteria based on comparison of macroinvertebrate measures with control sites.
North Carolina	Network Trend Monitoring (macroinvertebrates, phytoplankton) Special Site Studies (fish, macroinvertebrates, phytoplankton)	Administrative biological criteria support aquatic life use classes in standards. Developing detailed map of State to refine ecoregions.
North Dakota	None	None
Ohio	Network Trend Monitoring (fish, macroinvertebrates) Five Year Basin Approach* (fish, macroinvertebrates) ** A framework from which basins, sub-basins or mainstem surveys are selected on a priority basis on a five year rotation.*	Biocriteria are used in all surface water programs. Adopted (Feb. 1990) quantitative ecoregional biological criteria for fish and macroinvertebrate communities in water quality standards regulations. Using Index of Biotic Integrity and two other indices to rate streams. Currently assessing long-term trends and may develop ecoregional chemical criteria.
Oklahoma	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates, periphyton)	None
Oregon	Special Site Studies (fish, macroinvertebrates)	Planning for biocriteria development.
Pennsylvania	Network Trend Monitoring (macroinvertebrates) Special Site Studies (fish, macroinvertebrates, macrophytes)	None
Puerto Rico	None	None

Table 1 (continued)

STATE	BIOLOGICAL SURVEYS	BIOLOGICAL CRITERIA
Rhode Island	Network Trend Monitoring (macroinvertebrates) Special Site Studies (estuarine)	None
South Carolina	Network Trend Monitoring (phytoplankton, fish, macroinvertebrates) Special Site Studies	None
South Dakota	Special Site Studies (fish, macroinvertebrates)	None
Tennessee	Network Trend Monitoring (macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	Using a modified IBI to monitor basins, assess nonpoint source pollution, and determine attainable resource quality.
Texas	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	Narrative biological criteria are in the State's water quality standards and are used to support aquatic life uses. Ecoregion studies are currently being conducted on least disturbed Texas streams.
Utah	Special Site Studies (fish, macroinvertebrates)	None
Vermont	Network Trend Monitoring (fish, macroinvertebrates) Special Site Studies (fish, macroinvertebrates	Use in-stream biocriteria to determine if two biological standards are being met through an administrative rules procedure.
Virginia	Network Trend Monitoring (macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	Using biomonitoring and benthic programs to determine the degree of water quality impairment in streams. Planning for biocriteria is underway with preliminary sampling and evaluation of possible reference sites.
Virgin Islands	Special Site Studies (marine, fish, macroinvertebrates)	None
Washington	Special Site Studies (fish, macroinvertebrates)	None
West Virginia	Network Trend Monitoring (macroinvertebrates) Special Site Studies (fish, macroinvertebrates)	None
Wisconsin	Network Trend Monitoring (macroinvertebrates, phytoplankton)	Modifying IBI for subsequent development of biological criteria. Stream classifications are based on slope gradient and summer temperature.
Wyoming	None	None

CHAPTER 3



Case Studies of Biological Criteria Programs in Five States

Five States are using biological criteria to define aquatic life use classifications and enforce water quality standards. Ohio, Maine, and North Carolina have made biological criteria an integral part of comprehensive water quality programs. Florida and Arkansas are using biological criteria for specific water quality problems in their streams and rivers.

■ OHIO

Ohio has taken the most comprehensive approach to developing biological criteria as a replacement for best professional judgment (BPJ) evaluations of surface water quality. To ensure that biological evaluations would be applicable to all its surface waters, Ohio based biological criteria on ecoregions and regional reference sites. Criteria for the Index of Biotic Integrity (IBI), Invertebrate Community Index (ICI), and Modified Index of Well-being (MIwb) have been developed for different site types within each ecoregion. These numeric indices provide specific quantitative measures that must be met to attain the tiered aquatic life uses stipulated in Ohio's water quality standards.

Upgraded use designations based on biological criteria have been upheld in Ohio courts, and an appeal of these decisions has been recently sustained in Ohio EPA's favor. As of February 1990, the Ohio EPA has adopted biological criteria in the State water quality standards regulations.

Derivation of Biological Criteria

Biological criteria for Ohio surface waters are based on the biological community performance that can be attained at regional reference sites. This is consistent with the definition of biotic integrity as discussed by Karr and Dudley (1981), Hughes et al. (1986), and Karr et al. (1986). Ohio's biological criteria represent ecological structures and functions that can be reasonably attained given present-day background conditions (Whittier et al. 1987); they do not attempt to define pristine, pre-Columbus conditions (Hughes et al. 1986). The biocriteria system does allow, however, for future adjustments based on long-term changes in background conditions. Ohio will determine the need to make adjustments to the biocriteria, biological indices, or both concurrently with the triennial water quality standards review.

The Ohio EPA uses three biological indices. Two are based on fish: the MIwb (Gammon, 1976; Gammon et al. 1981; Ohio Environ. Prot. Agency, 1987a) and the IBI (Karr, 1981; Fausch et al. 1984). The third, the ICI, is based on macroinvertebrates (Ohio Environ. Prot. Agency, 1987a). Previously, the State used traditional biological measures such as diversity indices and taxa richness values that extracted a limited amount of ecologically meaningful and relevant information from the raw data.

Biological criteria derived from the indices vary according to organism group, biological index, site type, ecoregion, and aquatic life use designation. The geographic organization of Ohio biocriteria uses concepts from the Ohio Stream Regionalization Project (SRP) and the ecoregional-regional reference site approach (Omernik, 1987; Hughes et al. 1986; Whittier et al. 1987). MIwb and IBI criteria have been defined for each of the five Ohio ecoregions for three site types: headwaters (drainage area < 20 square miles), wading sites (streams sampled with wading methods, usually 20 to 300 square miles), and boat sites (streams and rivers sampled with boat methods, usually 200 to 6,000 square miles). ICI criteria are based primarily on an artificial substrate sampling method and incorporate stream size differences based on drainage area. The calibration of the indices and the resultant biocriteria consider the effects of stream size and sampling gear selectivity.

Biological data from the reference sites have been used to calibrate the biological indices and to establish ecoregional biocriteria for all three indices. The individual metric scores must be calibrated for both the IBI and ICI. Sampling results from reference sites were pooled statewide to derive metric scores; procedures generally followed those described by Fausch et al. (1984) and Karr et al. (1986). Several of the IBI and all of the ICI metrics vary according to stream size. A relationship between drainage area (square miles) and each individual metric was used to determine the IBI and ICI scoring ranges for each.

Once the biological index scores for each reference site were calculated, box plots were constructed for each biological index by ecoregion and site type. These plots contain sample size, medians, ranges with outliers, and 25th and 75th percentiles. Box plots were preferred over means and standard deviations because they do not assume a particular distribution of the data. Furthermore, outliers do not exert as much influence on box plots as they do on means and standard errors. Ecoregional biocriteria for Ohio's warmwater habitat use designation are established as the 25th percentile value of the biological index scores recorded at the reference sites by ecoregion. For Ohio's exceptional warmwater habitat use designation, biocriteria are based on the combined statewide reference site data set and index criteria are set at the 75th percentile value.

Both warmwater and exceptional warmwater habitats are defined in narrative terms in the Ohio water quality standards and reflect attainment of the "fishable-swimmable" goals of the Water Quality Act. In addition, a modified warmwater habitat use designation is being proposed because certain waterbodies have been so physically modified that a warmwater habitat use is unattainable. These biocriteria were determined from a separate set of modified reference sites. The format of the biocriteria proposed in Ohio's water quality standards is illustrated by the accompanying IBI values for wading sites for each ecoregion (Table 2).

Application of Biological Criteria

The longitudinal study design (i.e., tracking the status of an aquatic resource over time) is fundamental to Ohio EPA's biological monitoring approach and an important factor in determining waterbody-specific regulatory options. Longitudinal study results also document improvements emanating from pollution abatement over a given period. For example, the general improvement in the IBI in the Scioto River (downstream from Columbus, Ohio) between 1979 and 1987 corresponds to overall reductions in wastewater treatment plant loadings of suspended solids, ammonia, nitrogen, and biochemical oxygen demand (Figure 3). The effluent loading reductions were most consistent at the wastewater treatment plant farthest downstream, particularly at

Table 2.—Format of the biocriteria in the Ohio water quality standards regulations for the Index of Biotic Integrity and wading sites for fish (comparable tables exist for other indices and site types).

INDEX/SITE TYPE ECOREGION	MODIFIED WARMWATER HABITAT (MWH)				
	Channel Modified	Mine Affected[a]	Impounded[b]	Warmwater Habitat (WWH)	Exceptional Warmwater Habitat (EWH)
I. Index of Biotic Integrity (fish)					
A. Wading Sites					
1. Huron/Erie Lake Plain	22			32	50
2. Interior Plateau	24			40	50
3. Erie/Ontario Lake Plain	24			38	50
4. W. Allegheny Plateau	24	24		44	50
5. Eastern Corn Belt Plain	24			40	50

[a] Applies to W. Allegheny Plateau ecoregion only.
[b] Applies to boat site type only.

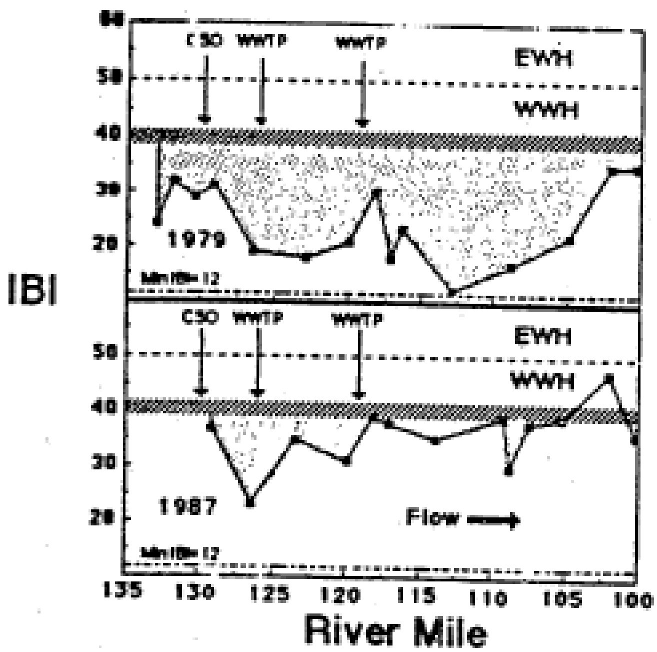


Figure 3.—Longitudinal trend of the Index of Biotic Integrity for the Scioto River in and downstream from the Columbus, Ohio, metropolitan area in 1979 and 1987. Major water quality impacts are indicated (vertical arrows), and flow direction is from left to right (descending river mile order). Source: Ohio Environmental Protection Agency (1987b).

the plant bypass. In contrast, although historical loading reductions did occur at the upstream wastewater treatment plant, they were not entirely consistent with substantial increases noted during 1984 to 1987.

These data correspond to a continued significant impairment of the warmwater habitat use that extends several miles downstream of the upstream facility; however, neither wastewater treatment plant was using advanced treatment technology during the 1987 sampling. Other evidence that biological stress remained in 1987 included an increased number of eroded fins, lesions, and tumors on individual fish. Follow-up sampling continued in 1988 and 1989 to assess the effects of further anticipated loading reductions. According to a 1986 U.S. General Accounting Office report, State and Federal strategies to assess the direct benefits of improved wastewater treatment lack analyses that compare in-stream response with effluent loadings over time.

Biological field data have also led to the discovery and improved understanding of significant environmental problems that otherwise would have gone unnoticed or received less critical attention. An example is the toxic impact of the Akron Wastewater Treatment Plant on the fish and macroinvertebrate communities of the Cuyahoga River. The magnitude, severity, and pattern of the response indicated a severe toxic impact unlike the usual response observed downstream from most of these facilities. According to in-stream and effluent monitoring data, conventional parameters such as dissolved oxygen, ammonia, and phosphorus improved to levels that are generally compatible with healthy aquatic communities. Concurrent and follow-up bioassay testing showed acute toxicity in the influent, effluent, bypass, and receiving stream in 1984 and 1986. Toxicity was reduced in late 1985 and substantially lower in 1986.

In 1985 and 1986, the fish community underwent modest structural improvements (e.g., higher number and biomass of tolerant species); however, it was functionally degraded and showed the remaining effects of significant toxic stress. Of particular note were the very low IBI and the remaining high incidence of skeletal deformities and other anomalies in fish, findings that indicate continued subacute stress. This is a classic example of how toxic problems can be discovered, quantified, and identified by measuring in-stream biological community response. In this situation, the use of chemical sampling or bioassay testing alone could have significantly underestimated a serious, continuing, environmental problem.

The result of a 1986 survey of the Little Cuyahoga River subbasin shows how biological data can reveal environmental degradation that would otherwise have gone unnoticed. The pattern of biological community response indicated severe toxic impacts in the upper and middle portions of the main stream and impacts of a combined toxic and organic sewage problem in the lower segment; however, there were no violations of chemical water quality standards under low flow conditions. Visual observations reported good water clarity and no extensive sludge deposits.

In contrast, the biological response in the middle portion of the Little Cuyahoga River indicated the severe impact of toxic substances. Several point sources located in this segment are authorized to discharge noncontact cooling water and sanitary wastes. Most of the permitted facilities manufacture plastic and rubber; therefore, they use and handle organic chemical products. The observed in-stream biological response indicates that contamination of the receiving stream is occurring frequently enough to keep the resident biota suppressed. A follow-up investigation of the study area could focus on how chemicals are reaching the stream—either through combined sewer overflows or unauthorized discharges. In this case, current NPDES monitoring and discharge requirements may be inadequate.

The Cuyahoga and Little Cuyahoga River examples demonstrate the value of biological field evaluations in supplementing chemical-specific and bioassay strategies for point sources. Toxics programs currently concentrate on process analyses of the wastewaters. A significant concern with this approach is its inability to accurately assess and characterize impacts that occur through runoff, "non-contact" cooling water, spills, and dumping—all pathways to the receiving waters other than process discharges. Chemical sampling, biosurveys, and bioassay testing provide complementary results, therefore concurrent use of all three approaches is recommended (Ohio Environ. Prot. Agency, 1987b).

History

Development of Biological Criteria

Ohio has intensively surveyed the biological communities and water quality of its surface waters since 1979. These efforts were initially designed to add a biological component to evaluations that had been historically based solely on chemical and physical data. The State also wanted to develop a protocol (other than by best professional judgment) for assigning the newly adopted tiered system of aquatic life uses to individual streams and rivers. By 1980, use of biological data in assigning aquatic life uses to surface waters was firmly established.

In 1981, Ohio was awarded a construction grants program to deal with water treatment issues, which necessitated expansion of the biological and water quality survey program. Overlapping NPDES permit issues were included, along with the existing concerns of the water quality standards program. In 1983 and 1984, Ohio conducted a joint project with EPA's Environmental Research Laboratory (ERL) in Corvallis (Oregon) to determine the feasibility of organizing and evaluating biological and water quality data by ecoregions. The success of this project led to the eventual development of Ohio's ecoregion-based biocriteria in 1987.

Since 1984, the biological and water quality survey program and associated techniques have been used to evaluate nonpoint source impacts, toxicants, antidegradation issues, spills, combined sewer overflows, hazardous wastes, posttreatment upgrades, and habitat modifications. Recently, the role of this program in litigation and enforcement has begun to be realized. The data collected in these surveys have facilitated discovery of previously unknown impairments and an enhanced understanding of poorly defined problems. The information provided by this program has been useful for virtually all regulatory, resource protection, and monitoring and reporting programs pertaining to surface waters.

Current Status of Biological Criteria

Ohio EPA's Surface Water Section conducts approximately 10 to 12 biological surveys with an average effort of just over 13 work-year equivalents per year (based on actual Federal fiscal year 1987 and 1988 data). This total is down from the 15 to 20 surveys conducted yearly during the biocriteria development phase between 1983 and 1986. Approximately 26 percent of Ohio EPA's Division of Water Quality Planning and Assessment resources are devoted to field, assessment, and laboratory activities.

New initiatives present the possibility of a continuation, if not an outright expansion, of the existing level of effort. Potential new areas of involvement include supporting projects within the Ohio EPA Division of Emergency and Remedial Response, Ohio Senate Bill 180, Lake Erie initiatives, and several miscellaneous projects.

The 1989 Ashtabula River Survey, made at the request of the Division of Emergency and Remedial Response, was the first official effort in support of natural resource damage assessment (NRDA). The biocriteria and associated impairment quantification approaches are particularly useful for NRDA types of projects. Senate Bill 180, if passed in a suitable form, could provide additional resources for field and data evaluation associated with NPDES permit issues, which would coincide with existing efforts and help to offset impending declines in Federal grant support.

Currently, Ohio EPA's resources will cover approximately 75 percent of the NPDES issues that need at least one biosurvey evaluation. The agency has instituted a "five-year basis approach" to NPDES permit reissuance and ambient support monitoring. This rotating basis system is designed to promote more efficient use of ambient monitoring resources and ensure timely results.

Anticipated benefits of continuing the existing survey program include follow-up evaluations of newly constructed or upgraded treatment facilities and responses to concerns about current water quality-based permit limits, particularly "low" metal limits. The Lake Erie initiatives include an effort to refine aquatic life assessment criteria and conduct the basic monitoring needed to characterize problems in the Lake Erie tributary river mouth and harbor areas. Other areas include interactions with environmental groups—such as The Nature Conservancy—and with nongame programs sponsored by the Ohio Department of Natural Resources.

Discussion

Program Resources

Since Ohio's quantitative biological surveys began as a grass roots effort in the late 1970s, it is difficult to identify all of the resources that went into initial development of biological criteria. In addition, a critical part of the program was basic research into the ecoregion concept that serves as the basis for the reference site evaluations in the criteria. Ohio was one of three test States for EPA ERL-Corvallis' Stream Regionalization Project, which developed general concepts, procedures, and specific maps that greatly aided other States that were initiating ecoregional biocriteria programs and undertaking similar habitat classification research.

In Ohio, the sampling required for the reference site system (approximately 300 sites) was accomplished over an eight- to nine-year period. Although most reference sites were sampled in 1983–84, costs for other States could be spread out over a longer period. Ohio's cost estimates for ecoregional criteria development are $222,000 for fish sampling (300 sites at 2.1 work-year equivalents) and $247,200 for macroinvertebrate sampling (300 sites at 4.8 work-year equivalents), for a total of $469,200 or approximately $1,500 per site for both fish and macroinvertebrates. Thinly populated States will need approximately $50,000 to develop a reference site system, while very heavily populated States might need more than $500,000. In Ohio, regular reference site survey efforts are spread over several programs, and about 10 percent of the sites are resampled each year. Other States' existing survey programs may provide an adequate database.

Ohio EPA has operated an intensive stream and river survey program since 1977. In the last 10 years, the program has assessed more than 500 streams, rivers, and lakes covering nearly 8,000 miles by using standard field collection and data analysis techniques. Fish have been monitored at nearly 3,000 locations, macroinvertebrates at nearly 2,200 locations, and chemical and physical water quality at nearly 2,300 locations (with an average of three to five samples per location) in each individual segment and basin evaluation. More than 950 point source discharges have been evaluated for environmental impact. Overlapping nonpoint source influences and previously unknown or unqualified impacts, such as combined sewers, bypasses, and unauthorized discharges, were identified and evaluated in many areas, and monitoring in support of wasteload allocations and whole effluent toxicity assess- ments was performed as well.

This history of using a standard and systematic application of biological field monitoring techniques, along with more traditional chemical, physical, and recently emerging bioassay assessments, has allowed a detailed comparison of the costs of each component. Out of the nearly 100 work-year equivalents devoted to monitoring and laboratory activities within Ohio's Division of Water Quality Planning and Assessment in Federal fiscal years 1987 and 1988, biosurvey activities used 19.34 work-year equivalents or just over 19 percent of the division total. By comparison, activities related to toxics and permit support used 26.45 work-year equivalents (26 percent), chemical sampling and laboratory analysis 36.18 work-year equivalents (36 percent), and other activities (general technical assistance, enforcement, 401 program, 305b report) 17.96 work-year equivalents (19 percent).

Comparative Cost Calculations

The costs of fish, macroinvertebrate, and chemical and physical grab sampling and bioassay evaluations were calculated using Federal fiscal year 1987 and 1988 data available from Ohio EPA's Time Accounting System and Integrated Work Programs and were submitted to EPA for each fiscal year. Cost items considered were personnel (salary, fringe benefits, and overtime), supplies, equipment, travel, communication, utilities and rent, maintenance, computer charges, printing, and miscellaneous expenses.

An attempt was made to account for the unique requirements of each monitoring component. For example, the equipment costs for the fish, macroinvertebrate, and bioassay monitoring were amortized over periods ranging from 5 to 10 years. For other cost categories, such as rent and utilities, the percentage of the work-year equivalents devoted to each monitoring component was used to determine the share of such costs based on the total budget (Table 3). A factor of 23 percent was assessed to reflect fringe benefits and other indirect costs.

Administrative support costs common to each of the monitoring components were not included because they are shared equally and would be

Table 3.—Ohio EPA personnel costs in Federal fiscal years 1987 and 1988 (less 23 percent fringe factor) for surface water quality program activities.

PROGRAM	WORK-YEAR EQUIVALENTS			DOLLARS		
	1987	1988	Total	1987	1988	Total
Biological Field[a]	9.82	9.52	19.34	275,763	280,518	556,281
Toxics/Permits[b]	13.96	12.49	26.45	343,594	384,276	727,870
Chemical/Lab[c]	16.72	19.46	36.18	409,663	517,367	927,030
Other[d]	7.55	10.41	17.96	245,263	325,423	570,686
TOTAL	48.05	51.88	99.93	1,274,283	1,507,584	2,781,867

[a] Includes field sampling, data analysis, data interpretation, biocriteria development, QA/QC methods, and integrated interpretation of biological and chemical information and reporting.

[b] Includes water quality standards and criteria, wasteload allocation modeling, bioassays, and production of water quality-based effluent limit reports.

[c] Includes chemical water quality field sampling for surveys and NAWQM and chemical analysis at the Water Quality Laboratory.

[d] Includes 305b report, Lake Erie/IJC RAP activities, 401 certification, lakes program, district activities (complaints, compliance sampling), enforcement support, and general technical assistance.

provided even if a component is eliminated. After total costs are calculated, the cost per unit is derived by using work outputs from Federal fiscal years 1987 and 1988. Costs are broken down by sample collection, laboratory analysis, test, evaluation, and all data analysis and interpre- tation activities as appropriate for each component.

For fish community assessment, the cost per sample was $340 and the cost per site, $740. (The cost difference reflects multiple sampling in certain sites.) Standard electrofishing techniques are used, and each site is sampled once, twice, or three times (depending on type of sampler and stream size) during the summer (June through early October). These semi-quantitative methods measure relative abundance (in contrast to population and standing crop estimates).

Macroinvertebrate sampling costs $824 per site for artificial substrates (which includes qualitative dip net monitoring) and $275 per sample for qualitative dip net efforts only. Artificial substrate data are collected by using composite samples of five artificial substrate samplers sets for six weeks during the summer. Qualitative samples from the natural substrate are collected at the time artificial substrates are retrieved and figure in the $824 cost. Some smaller streams can be sampled through qualitative techniques alone.

The cost information presented here is contrary to the widely held view that collecting biological field data is unusually expensive. The cost effectiveness demonstrated in this assessment can be attributed to a standard, systematic approach to study design, field methods, and data analysis. The information and analysis presented in this assessment demonstrate that biological field monitoring is cost competitive with chemical, physical, and bioassay monitoring components when using a reasonable and systematic approach to data collection. Water monitoring programs are faced with two competing objectives: (1) the need to evaluate as many sources as rapidly as possible, and (2) the need to have valid, accurate, and complete data on which to base and defend decisions. A program that judiciously uses an appropriate mix of chemical-specific, bioassay, and biosurvey components should adequately meet these objectives.

While the foregoing analysis discusses relative monitoring costs, complete assessments of the environmental costs of biological field monitoring programs should also consider the negative consequences to decisionmaking and regulatory actions that can result from not having an adequate understanding of an aquatic system.

Program Evaluation

Three important lessons were learned from Ohio's experience with biological criteria:

- Crucial decisions made on what information to collect have long-term consequences;
- A standard system for consistent data collection and analysis is essential; and
- Only adequate representative samples, rather than exhaustive inventories, are needed at each site.

The decision to use a standard system kept the program sufficiently flexible to accommodate new water quality objectives and changing data evaluation methods. Ohio undertook test sampling to determine the sample sizes necessary for drawing valid conclusions and thus, by limiting sampling effort, demonstrated that biological sampling is cost effective.

By adhering to these three principles, Ohio's biological criteria program was able to evolve from an initial qualitative assessment of benthic communities (good, fair, or poor, based on best professional judgment) to a quantitative set of ecological indices—IBI, MIwb, and ICI—based on comparisons with ecoregional reference sites. For Ohio, the outgrowth of the Stream Regionalization Project of 1983–84 was the refinement of quantitative indicators, including the develop- ment of their own Invertebrate Community Index, and the eventual adoption of biological criteria in water quality standards.

A third and still partially unresolved problem encountered during this process was the difficulty in communicating the principles and advantages of biological criteria to nonbiologists. Administrators unfamiliar with this approach often viewed it as unnecessary or overly expensive. Ohio has learned that it is essential to emphasize the link between biological criteria and the ability to make better decisions relating to water quality regulations. Knowledge of the importance of this link must be communicated to agency personnel, EPA, legislators, and the regulated community.

Ohio has attempted to communicate through a series of recently instituted three-day training sessions on water quality surveys and permit procedure. These programs, which were held in each of our five district offices, were successful in breaking down some of the barriers to communication. For further information, contact Chris Yoder, Ohio Environmental Protection Agency, 1800 Watermark Drive, P.O. Box 1049, Columbus, OH 43266-0149; (614) 466-1488.

MAINE

To improve its surface water management capabilities, Maine is applying a biological approach to water quality classifications and criteria. In April 1986, after four years of negotiation with industry and environmental groups, the Maine legislature enacted the revised Water Quality Classification Law, which includes language specifically designed to facilitate biological assessments. Each waterbody class lists the descriptive aquatic life conditions necessary to attaining it. To implement the new classification system, the Maine Department of Environmental Protection has developed specific biological criteria that will be used to support the statutory aquatic life uses in the Water Quality Classification Law.

Development of Biological Criteria

The initial water quality classification system for Maine was developed in the 1950s and survived, essentially unmodified, through the early 1980s. During that period, dramatic changes occurred in Maine's water quality, regulatory policy, and the sophistication of available assessment techniques. After State and Federal restrictions were placed on the discharge of pollutants, water quality improved and the public's perception of uses for the State's aquatic resources changed. The original use classification law contained unrealistically restrictive aquatic life standards that were undifferentiated by water quality class and were, therefore, unenforceable. For these reasons, the Bureau of Water Quality decided to overhaul the use classification system.

Administrators at the Water Bureau recognized that in-stream biological surveys provided important information that was generally unavailable. Staff with advanced training and experience in using benthic macroinvertebrates in water quality assessments had been collecting macroinvertebrate data since the mid-1970s to evaluate point source and nonpoint source impacts; therefore, they had developed a fairly sophisticated understanding of how biological communities in Maine's rivers and streams responded to environmental stress.

With this basis, the Department of Environmental Protection's Water Bureau began to revise the use classification law to define different levels of ecological integrity for each classification. Concurrently, they developed a standard macroinvertebrate sampling regime and began surveys above and below all major point sources in the State as well as in a diversity of undisturbed river and stream reaches. The new classification system was then ushered through the lawmaking process. Two macroinvertebrate biologists drafted the aquatic life standards and interpreted and negotiated the law's language with legislators, dischargers, and environmental conservation groups.

Water quality standards in the Maine law were written to be broadly applicable. Specific implementation is accomplished through a set of rules or regulations that can be changed to accommodate advances in assessment techniques. These rules (the numeric and qualitative biological criteria) are currently being developed from the empirical findings and statistical analyses of the standard macroinvertebrate database.

Program Rationale

The need to revise the classification law opened up the possibility of expanding the roles of biological information both in program planning and as a feedback loop to evaluate overall water quality management efforts. The Water Bureau believed that the creation of explicit aquatic life standards would ensure active consideration of aquatic life resources in management decisions and give a statutory basis for enforcing and managing discharges harmful to aquatic life.

Macroinvertebrates were chosen to be the representative subcommunity because of their practical and theoretical advantages as indicators and because staff with substantial familiarity and technical expertise with these organisms worked within the Water Bureau—two masters-level aquatic entomologists, both with masters' theses on the use of aquatic invertebrates in water quality assessment and extensive field experience.

History

Derivation of Biological Criteria

The 1986 law that revised Maine's water classification system was not designed to change existing water quality levels but to improve the Department of Environmental Protection's ability to monitor and manage surface waters. Under a previous law, a single aquatic life statement—"Discharges shall cause no harm to aquatic life"—applied to four water quality classes. Countless biological studies demonstrated that it was impossible to enforce this restrictive statement across all classes of effluent-receiving waters. Maine waters that were clearly attaining the minimum chemical and physical standards of the lowest class could not meet the "no harm to aquatic life" criterion because some sensitive indigenous species had been displaced.

The revised classification system has classes of different quality and therefore, different aquatic life uses, including both pristine recreation-oriented waters and waters of lesser quality with industry and agriculture. The 1986 law defines different levels of aquatic life use (ecological integrity) for each water quality classification (Table 4) and also specifies bacteria and dissolved oxygen criteria.

With its refined biological classification system and standard benthic macroinvertebrate database in place, Maine has identified sets of significant, measurable ecological attributes associated with each aquatic life standard (Table 5). For example, the State's highest water quality class—AA—has a standard stating that "aquatic life shall be as naturally occurs." The ecological attributes identified for this standard are taxonomic equality (as compared to a pristine reference site), numerical equality (as naturally occurs), and the presence of pollution-intolerant indicator taxa. The identification of ecological attributes associated with each standard allows designation of indices and measures of macroinvertebrate community structure that are most sensitive to the evaluation of sets of attributes.

For example, for Class AA, the set of metrics includes measures of similarity, abundance, richness, EPT (pollution-intolerant Ephem- eroptera, Plecoptera, and Trichoptera), lists of indicator taxa, and biotic indices. Criteria are derived from statistical evaluation of the statewide database and are designed to provide a pass, fail, or no decision test specific to each class (Courtemanch and Davies, 1989), rather than arbitrary ranks of good, fair, or poor. A linear discriminant model is constructed that provides a probability that a community fits a particular class. The data set is also tested using in-

Table 4.—Classification scheme for aquatic life uses in Maine's fresh waters.

WATERBODY	MANAGEMENT PERSPECTIVE	LEVEL OF INTEGRITY
Rivers and streams Class AA	High quality water for preservation of recreational and ecological interests. No discharges of any kind permitted. No impoundment permitted.	Aquatic life shall be as naturally occurs.
Class A	High quality water with limited human interference. Discharges restricted to noncontact process water or highly treated wastewater of quality equal to or better than the receiving water. Impoundment permitted.	Aquatic life shall be as naturally occurs.
Class B	Good quality water. Dischargers of well-treated effluents with ample dilution permitted.	Ambient water quality sufficient to support life stages of all indigenous changes in community composition may occur.
Class C	Lowest quality water. Requirements consistent with interim goals of the Federal Water Quality Act (fishable and swimmable).	Ambient water quality sufficient to support the life stages of all indigenous fish species. Changes in species composition may occur but structure and function of the aquatic community must be maintained.
Lakes and ponds Class GPA	Preservation of their natural quality to sustain a variety of habitats and recreational uses. No new discharges allowed in their tributaries.	Trophic state shall be stable or decreasing. Water shall be free of culturally induced algae blooms.

Table 5.—Determination of biological standards for Maine surface waters.

LEVEL OF INTEGRITY	ECOLOGICAL ATTRIBUTES	METRICS
Natural	Taxonomic equality Numeric equality Presence of intolerant taxa	Percent similarity, taxonomic similarity, total abundance, richness, EP, indicator taxa, biotic index
Unimpaired	Retention of taxa Retention of numbers Absence of hyperdominance Presence of intolerant taxa	Coefficient of community loss, richness, diversity, EPT, relative taxa abundance, functional feeding groups, indicator taxa, biotic index
Maintain structure and function	Balanced distribution Redundance Resistance to change Resource assimilation	Coefficient of community loss, richness, diversity, relative taxa abundance, total abundance, indicator taxa, functional feeding groups

dicator taxa and comparative indices to further verify placement in a particular classification.

Application of Biological Criteria

In Maine, both chemical-specific and effluent toxicity criteria are used to evaluate water quality treatment, while ambient biocriteria provide evaluations of aquatic life use attainment. Within the textile industry, Maine has found numerous situations where reliance on only one or two of these types of criteria would have incorrectly indicated compliance with a designated use category. In one example, chemical-specific and effluent-toxicity criteria were in compliance, yet evaluation of the resident biological community found declines of up to 80 percent in macroinvertebrate richness and numbers. Positive in-stream findings of nonattainment serve to trigger cooperative problem identification and resolution among biologists, operations and maintenance engineers, enforcement staff, and technical staff employed by the discharger. The primary goal of Maine's Department of Environmental Protection in-stream biomonitoring program is to provide feedback concerning the results of State efforts to protect aquatic life resources. The program is not expected to play a significant role in permit writing; however, information from it will be used to assess the degree of protection afforded by effluent limitations. As the freshwater biomonitoring program is becoming operational, the State is developing a marine biomonitoring and biocriteria program.

Discussion

Program Resources

Initially, one full-time and two part-time administrative and planning biologists worked in the biological effort; most of the taxonomic identification and sample sorting was contracted out. A contractor was hired to program the database management system, and State university faculty contracted to give professional statistical advice. A second full-time aquatic biologist was hired in December 1988, when the two part-time biologists significantly reduced their day-to-day activities. During the summer field season, a quarter-time or half-time summer student assisted in field activities and data editing.

The annual salaries for the full-time biologists range from $25,000 to $30,000 annually. The part-time biologists were employed for less than 20 percent of the time and drew full-time equivalent salaries of $33,000 to $35,000. The contracts for taxonomic work average $9,000 to $11,000 per year during intensive baseline data collection years. A somewhat lesser amount is expected during routine monitoring years.

Maine's Department of Environmental Protection received a $15,000 Supplemental 106 program grant through EPA Headquarters and Region I at the end of 1988; of this, the department spent $6,000 on a computer programming contract. The data management system uses dBASE III and Microsoft Excel on a IBM PS/2 Model 70 computer. Statistical support is funded through a $2,800 contract from the Supplemental 106 funding source.

The sampling gear used by the program—dredges, D-nets, wire baskets for artificial substrates, and homemade deep river samplers—is durable and costs less than $2,000. Most of the gear lasts 3 to 5 years, except for dredges, which last 10 to 15 years. The depart- ment's methods manual describes field, lab- oratory, and analytical techniques.

Program Evaluation

In 1983, Maine started sampling for baseline data. The law stipulating baseline monitoring was first drafted and submitted in 1982; then it was redrafted in different legislative sessions until becoming law in 1986. Intensive legislative committee negotiations consumed nearly a year and took precedence over advancing the technical aspects of the program. Because industry was wary about perceived radical changes in assessments and standards (impact standards versus traditional performance standards) that Maine was proposing, considerable time was spent trying to gain its acceptance.

Developing a data management system took a large amount of time because, initially, the department lacked a full-time programmer. Because the program was understaffed, improvement in technical aspects had to be delayed to sustain administrative momentum. Program staff have recommended that adequate backup personnel be hired for the extremely labor-intensive sampling and data-handling activ- ities. For further information, contact David Courtemanch or Susan Davies of the Maine Department of Environmental Protection, State House Station No. 17, Augusta, ME 04333; (207) 289-7789

■ NORTH CAROLINA

North Carolina has used its extensive biological monitoring program as the basis for developing administrative biological criteria to protect aquatic life in surface waters. The State uses standard biological methods to assess impairments of narrative water quality criteria that define the status of aquatic life. Biological classification criteria also define outstanding resource waters and high quality waters. Currently, North Carolina is evaluating ecoregions and stream size variables as a means to refine present use classifications.

Derivation of Biological Criteria

North Carolina has a variety of geographic zones and waterbody types. Criteria have been developed for each of the State's major geographical regions to measure the degree of impairment of resident biota. The resultant standard method follows a scientific protocol and allows for rapid and cost-efficient data collecting and processing. The method provides a good sample of the stream invertebrate community, relates well to chemical water quality, and is reproducible. Seasonal variability exists within different ecoregions, but the standard method provides data consistency within a rapidly growing database.

Biological information has been included in the water quality program in North Carolina since the mid-1970s. At first, in-stream benthic macroinvertebrate sampling was used extensively in support of the original 208 nonpoint source program; however, various qualitative and quantitative collection techniques have been instituted and evaluated for cost-effective data collection and as defensible assessments of streamwater quality. This assessment led to the development of a qualitative method that can be used to sample the entire benthos within a stream and collect numbers of total taxa and sensitive taxa—such as Ephemeroptera, Plecoptera, and Trichoptera.

Macroinvertebrate surveys provide excellent information in flowing, wadeable streams but are of limited value in lakes, large rivers, and estuaries. Where eutrophication problems are of special concern, phytoplankton populations are evaluated in association with physical, chemical, and hydrological analyses. Phytoplankton assessments are made by a scientifically accepted method and provide comparable data from various waterbodies throughout the State. Documenting existing and potential problems by these means has resulted in management decisions and use classifications that provide additional protection to these waterbodies.

North Carolina's regulations do not contain specific biological indices and metrics, yet biological data and biocriteria are intrinsically linked to the use classifications and the standards that protect these uses. These data and criteria are used extensively to identify waters of special concern and those of exceptional quality. Narratives for the protection of aquatic life are incorporated into both the regulations and standard biological methods and are used to assess impairments to water quality. Proposed revisions of North Carolina's water quality standards in the triennial review process address the use of biomonitoring data in use classification and antidegradation policy.

Application of Biological Criteria

All use classifications in North Carolina's regulations require protection of aquatic life. The least restrictive freshwater classification is for general waters (Class C) defined in the regulations as follows:

- **Class C:** freshwaters protected for secondary recreation, fishing, and aquatic life including propagation and survival; all freshwaters are classified to protect these uses at a minimum.

The State employs biological, chemical, and toxicological data to identify impairments to uses in-stream, define the sources (point or nonpoint) of impairment, and ensure that management decisions lead to appropriate corrective actions. More restrictive standards apply to drinking water supplies, including restrictions on types of discharges and requirements for local land management programs. Stricter limits to prevent bacteriological contamination have been developed for waters classified for organized swimming.

Aquatic life uses are also protected in coastal waters, which are defined as follows:

- **Tidal Saltwater Classifications (SC).** Class SC: saltwaters protected for secondary recreation, fishing, and aquatic life including propagation and survival; all saltwaters are classified to protect these uses at a minimum.

Again, more restrictive standards apply to waters identified as suitable for organized swimming (SB) and for waters classified as suitable for commercial shellfishing (SA). These restrictions include both point and nonpoint source controls.

There are supplemental classifications within the regulations to protect waters with unique features that require specific criteria or management tools (Table 6). Use attainability analyses, including biological data, define the segments or watersheds to which supplemental classifications are added.

Both high quality waters and outstanding resource waters require a rating of excellent by the biological criteria. The biological classification criteria for this determination, listed in Table 7, are used for free-flowing streams across the State. Work continues on addressing other variables such as ecoregions and stream size to expand or improve the resolution of the bioclassifications relative to water quality.

Table 6.—Supplemental use classifications in North Carolina's water quality standards.

USE	DESCRIPTION
Trout Waters (Tr)	Freshwaters protected for natural trout propagation and survival of stocked trout.
Swamp Waters (Sw)	Waters that have low velocities and other natural characteristics that are different from adjacent streams.
Nutrient Sensitive Waters (NSW)	Waters subject to excessive growths of microscopic or macroscopic vegetation requiring limitations on nutrient inputs.
Outstanding Resource Waters (ORW)	Unique and special waters of exceptional state or national recreational or ecological significance that require special protection to maintain existing uses.
High Quality Waters (HQW)	Waters rated as excellent based on biological and physical/chemical characteristics through Division of Environmental Management monitoring or special studies, all native and special native trout waters (and their tributaries) designated by the Wildlife Resources Commission, all water supply watersheds that are either classified as WS-I or WS-II or those for which a formal petition for reclassification as WS-I or WS-II has been received from the appropriate local government and accepted by the Division of Environmental Management, and all Class SA waters.

Table 7.—Biological criteria (S_{EPT})[a] for different regions of North Carolina used to determine water quality levels for specific use classifications.[b]

WQ Rating	Mountains	Piedmont	Coastal A[c]	Coastal B[d]
Excellent	> 41	> 31	> 27	> 11
Good	32-41	24-31	21-27	9-11
Good/Fair	22-31	16-23	14-20	6-8
Fair	12-21	8-15	7-13	3-5
Poor	0-11	0-7	0-6	0-2

[a] S_{EPT} - Taxa richness for Ephemeroptera + Plecoptera + Trichoptera

[b] Taxa richness values may need adjustment for seasonability and/or stream size

[c] Shallow, fast moving

[d] Deep, slow moving

The nutrient sensitive water classification requires a determination of existing or potential degradation relative to eutrophication; to make this determination, North Carolina uses phytoplankton data combined with measures of chlorophyll *a*, nutrients, and other limnological data. Target values are derived, nutrient budgets prepared, and management strategies (including point and nonpoint source controls) developed to protect uses in nutrient sensitive water watersheds.

The algal bloom program has successfully identified waterbodies that have impacts restricted to cove areas with problematic nutrients derived from a particular source or sources rather than an entire watershed. The following chlorophyll *a* standard, accompanied by biological data, provides a means to prohibit or limit discharges of waste into impaired waters.

- **Chlorophyll *a* (corrected):** not greater than 40 µg/L for lakes, reservoirs, and other slow-moving waters not designated as trout waters, and not greater than 15 µg/L for lakes, reservoirs, and other slow-moving waters designated as trout waters (not applicable to lakes and reservoirs less than 10 acres in surface area); the commission or its designee may prohibit or limit any discharge of waste into surface waters if, in their opinion, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this rule would be violated or the intended best usage of the waters would be impaired.

History

Development of Biological Criteria

Before 1974, North Carolina monitored water quality by collecting data for conventional pollutants in streams receiving poorly treated wastes bearing large amounts of biochemical, oxygen-demanding substances. A combination of special monitoring studies and an extensive ambient network documented the often severe impacts on North Carolina waters. At the time, the North Carolina Division of Environmental Management consisted entirely of engineers, chemists, and technicians. Transport and fate models were used to determine the extent and location of oxygen depletion points in streams.

In 1974, North Carolina's Division of Environmental Management hired its first biologist and began to use EPA-approved methods to gather data on plankton, periphyton, and benthos. As collection of in-stream biological data was new to the State, division managers had to be convinced of their value as a tool in water quality management. At the same time, staffing to assess in-stream water quality was expanded with 208 funds. New personnel provided increased expertise in macroinvertebrate ecology that was used to document nonpoint source impacts throughout the State. Although the division was diversifying by using new funding, it was not integrating the programs to fully use in-stream results and maximize staff efficiency. The parallel operation of two programs with the same objective exacerbated the problems of limited funds and staffing.

The biologists within the Division of Environmental Management recognized a need to develop a new macroinvertebrate sampling methodology. The artificial substrates then being used did not sample the entire benthic community, required repeated trips to the site, and were often found missing on return trips because of vandalism or high flows. Therefore, semi- qualitative techniques were developed (Lenat, 1988) that improved ways data were used for biological assessment and proved to be more cost effective. As a result, more useful criteria and bioclassifications are developed.

The impacts associated with cumulative loadings of nutrients into lakes and slow-moving rivers led the Division of Environmental Management to add expertise in limnology, phytoplankton analysis, and watershed modeling. The staff of the Water Quality Section, including planners, modelers, and biologists, worked together to develop management strategies for State watersheds that eventually lead to the additional classification of nutrient sensitive waters. This program provided cost-share funds to the agricultural community and required nutrient reductions of permitted dischargers throughout these basins. A statewide algal bloom program, initiated to document the occurrence and magnitude of algal blooms associated with fishkills or aesthetic problems, provided feedback to the regional offices, information to managers dealing with concerned citizens, and identification of areas that needed more intensive investigations.

In 1983, an Aquatic Toxicology Group was formed to complement the traditional water quality assessment of impacts from permitted discharges. This program has worked closely with EPA throughout its development and has become a unit within the division's Water Quality Section. Intensive surveys being conducted by this unit include the identification of causative factors of toxicity within the effluent and in-stream assessments by the biologists to verify the extent of impact in the receiving waters. "Tox limits" are now designated for all major and complex wastes within the NPDES discharge permits.

In 1981, a lakes program was initiated to identify the trophic status of public lakes throughout the State. Twenty to 30 lakes have been sampled each summer on a rotational basis to characterize their existing water quality status. This information has been useful in addressing public concerns and identifying lakes in need of more intensive work. The Intensive Survey and Biological Assessment groups are now located within the Ecosystems Analysis Unit, which collects, analyzes, and reports the chemical, physical, hydrological, and biological data needed for assessments.

Integration of biological and chemical data has identified impacts in cove areas and other poorly circulating waters before whole lake or whole estuary problems have occurred. The North Carolina Environmental Management Commis- sion has passed regulations that allow the director to limit nutrient discharges into areas that have been determined impacted or may be potentially impacted from excessive growth of macroscopic or microscopic vegetation. More intensive lake surveys are continuing in lakes with these problems.

Current Status of Biological Criteria

Catchments with water quality that exceeds the standards and criteria necessary to maintain a healthy aquatic community and support all existing use classifications have also been identified. New regulations include an antidegradation statement and use classifications that provide added protection. As previously mentioned, these classifications are outstanding resource waters and high quality waters, both of which are discussed in some detail in EPA's draft monitoring program guidance. It is important to note that, in these classifications, excellent water quality must be identified from both biological and chemical monitoring data. Staff biologists must survey to determine which watersheds and stream reaches should be given these new classifications.

Cumulative impacts associated with multiple discharges and nonpoint source inputs are the most difficult to identify through monitoring. North Carolina's Water Quality Program determined that measuring a second trophic level of organisms in free-flowing streams would aid assessments of such impacts; therefore, fish community structure surveys and (eventually) criteria will be developed to address this need. This work should be especially helpful in addressing impacts from sedimentation, which is one of North Carolina's largest pollution problems.

Discussion

Program Resources

The most important aspect of a new or expanding monitoring program is that it meet the needs of the administration by improving evaluative capabilities cost efficiently. As in any program, the scope of North Carolina's monitoring and criteria efforts is determined by available resources. Data use is driven by the regulations. In North Carolina, narrative biological criteria are tied to use classifications within the regulations and to a strong antidegradation statement. This structure, combined with the support of water quality managers and the Environmental Management Committee, has produced a program that can successfully conduct assessments for enforcement actions, management plans, nonpoint impacts, and impacts from NPDES discharges.

As programs grow, it will be important to maintain efficiency by integrating all aspects of monitoring. Biological, chemical, and toxicological surveys often address only one problem when a set of coordinated conclusions is needed. This coordination is enhanced if all monitoring efforts are located within one section in the organization. Program diversification through the addition of specialists in different aspects of monitoring is only as efficient as this coordination. Also, funding must increase as programs grow in response to additional management needs, or the quality and efficiency of the work will suffer.

Fluctuating funding is one of the most difficult challenges that face States' biological monitoring and criteria programs. In North Carolina, the 208 funds that provided expansion capabilities disappeared and a similar history applies to the 205 funds. Clean Lakes grants are short-term, and the fate of 319 funds is in question.

Water quality monitoring should be a stable and progressive process. Expanding programs on short-term or unpredictable funding is generally detrimental. North Carolina water resource staff feel that better decisions about the program's level of effort would be possible if the existing patchwork of funds were diverted to the 106 grant. A more stable source of Federal funding would allow the State to better deal with the balance of State and Federal funding and to maintain consistency in its program.

Program Evaluation

Biological information has become integrated into every phase of operations within the Water Quality Section. Narrative standards within North Carolina's Water Quality Regulations support the use of biological assessments in evaluating point and nonpoint source pollution as well as in identifying and protecting best uses of North Carolina's surface waters. Within North Carolina's program, biological assessments can accomplish the following:

- Identify temporal and spatial changes or trends in water quality,
- Analyze effects of point source pollutant discharges in streams,
- Screen for potential toxic impacts,
- Verify toxic in-stream impacts,
- Identify cumulative impacts for use in a watershed modeling approach,
- Provide use attainability analyses for determining existing and appropriate uses,
- Identify watersheds with water quality higher than existing standards,
- Provide data support for enforcement actions,
- Conduct ecosystem analyses for complaint investigations such as fishkills and aesthetic problems,
- Provide trophic status analyses for lake characterizations,
- Assess existing or potential impacts relative to nutrient enrichment,
- Supply data to support 401 review processes,
- Document improvements that result from wastewater facility improvements,
- Provide data support for 305b documents,
- Assess nonpoint source impacts, and
- Document in-stream improvements that result from implementation of best management practices.

For more information, contact Jimmie Overton, North Carolina Department of Environment, Health, and Natural Resources, 4401 Reedy Creek Road, Raleigh, NC 27607-6445; (919) 733-9960.

■ FLORIDA

Florida possesses a specific numeric biological criterion based on invertebrate species diversity. The strict construction of the statute in terms of sampling method and parameter computation allow this criterion to be used to enforce the water quality standard. However, the criterion is not flexible enough to be used with many other water quality problems.

Derivation of Biological Criteria

The main biological criterion in Florida's various rules is biological integrity, which is defined legally as follows:

"The Shannon-Weaver diversity index of benthic macroinvertebrates shall not be reduced to less than 75 percent of established background levels as measured using organisms retained by a U.S. Standard No. 30 sieve and, in predominantly fresh waters, collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 m² area each, incubated for a period of four weeks; and, in predominantly marine waters, collected and composited from a minimum of three natural substrate samples, taken with Ponar-type samplers with minimum sampling area of 225 square centimeters."

This definition mandates the type of sampling to be used for different habitats (Hester-Dendy artificial substrates for fresh water and Ponars for marine areas) as well as the number of samples to be taken. The number of grabs making up one replicate for natural substrate samples is not in the rule but is included in a standard operating procedure manual. Also, the rule calls for "established background levels" of the Shannon-Weaver diversity index (*d*). The Shannon-Weaver Diversity Index is defined as "negative summation (from i=1 to s) of $(n_i/N) \log_2 (n_i/N)$ where s is the number of species in a sample, N is the total number of individuals in a sample, and n_i is the total number of individuals in a species i" (Fla. Dep. Environ. Reg. 1988a).

The Florida rules basically say *d* cannot be reduced to less than 75 percent of established background. However, a new rule for the use of certain types of wetlands for advanced secondary domestic wastewater effluent disposal also has a biological integrity standard that allows for a 50 percent reduction in *d* value (Fla. Dep. Environ. Reg. 1988b). Considerable biological monitoring, including macroinvertebrates, is required and since most wetlands are naturally stressed ecosystems, this rule will undoubtedly need modification after data are gathered for a few years.

Application of Biological Criteria

Biological criteria are used mostly in support of Florida Department of Environmental Regulation decisions and not strictly as prima facie evidence when chemical parameters are used. It is difficult to assess how instrumental biological criteria have been in swaying a hearing officer or judge. Biologists are continually challenged when explaining biological parameters and concepts to nonecologically oriented judges.

Some uses of biological criteria in Florida include support for:

- Point source and dredge/fill permit denials,
- Permit compliance evaluation,
- Determining needs for wasteload allocations, and
- Designation of outstanding Florida waters, a special protection category where an unusually high *d* value can help determine "exceptional ecological significance" (Fla. Dep. Environ. Reg. 1988c).

Use of biological criteria in enforcement may have the greatest impact in the following types of cases:

Type of Case	*Resolution*
Citrus concentrate spills	Out-of-court monetary settlements
Wastewater treatment plant discharges	Out-of-court monetary settlements
Battery toxic waste discharge	$11 million judgment (none collected because discharging company declared bankruptcy)
Toxic waste/oil spills	Out-of-court monetary settlements
Mining/spoil spills	Out-of-court monetary settlements
Lake filling	Injunction hearing in Circuit Court, District Court of Appeals overrule; trial in Circuit Court with cleanup and monitoring settlement costing $300,000

History

Biological criteria have been used for water quality evaluation in Florida since 1950. However, they gained some legal status only relatively recently when the Department of Environmental Resources adopt a macroinvertebrate standard.

The Shannon-Weaver diversity index (*d*) criterion was developed in Florida in 1975 and incorporated into the Florida Administrative Code Water Quality Rules in 1978. Florida had experience with *d* in lake work dating back to 1969. The lack of precision of natural substrate grabs for reproducibility of *d*, especially in lotic ecosystems, threatened this parameter in the hearings; therefore, artificial substrates were mandated for all freshwater sampling.

Many biologists in Florida wanted a qualitative index such as Beck's Biotic Index, especially since its use in Florida dated back to 1950 (Beck, 1954, 1955). However, it was dropped from the rule proposal because it applies only to flowing fresh water and organic pollution (low dissolved oxygen). In addition, the index was found too sensitive to the presence of even one individual of a rare species.

Discussion

The biological integrity standard (*d*) appears in Florida's rules for surface water and wetlands 12 times. Unfortunately, it also appears three times in the Florida statutes with a totally different meaning: referring to the pruning of mangroves. Therefore, regulators should be aware of potentially conflicting meanings in the rules and statutes.

Florida also has designated a vegetative index as a biological criterion to determine State jurisdiction in dredge and fill permitting. In determining this index, two exotics and three ubiquitous native species (including the cabbage palm) are designated as "invisible" species and not to be used in calculating the index (Fla. Dep. Environ. Reg. 1988c). This approach might be applied when determining macroinvertebrate diversities if data are skewed because of the abundance of opportunistic species such as *Chaoborus, Rheotanytarsus, Corbicula,* hydropsychid caddisflies, and simuliids). In such cases, the community structure can change completely without violating the rule. For example, while one Florida dredge and fill spoil case was being litigated, the degraded site (originally with a *d* value reduced by 80 percent) became colonized by a silt-tolerant community that elevated the *d* value back to more than 75 percent of background.

Several aspects of the statutory biocriteria for fresh water can present problems. For example, artificial substrates are inappropriate in some areas (such as the open water area of lakes); require time for incubation; are subject to vandalism; and are of limited use where water levels fluctuate greatly. Allowing a 25 percent reduction of *d* value in surface water and 50 percent in wetlands appears to be too lenient, especially since the measures are logarithmic. Additionally, it is often difficult to establish a background *d* value. Fortunately, the EPA ecoregion approach should help in establishing background where historical data do not exist. No flexibility exists in the Florida rules interpretation, as for example when drastic variations in *d* occur as a result of natural causes such as seasonal effects. Therefore, giving nonbiologist administrators, lawyers, planners, and engineers a *d* value without supporting explanations inevitably causes problems.

Overall, biological criteria are working in Florida. However, revisions and additions to the standards are warranted and will be handled through the routine EPA triennial rule review process. For more information, contact Jim Hulbert, Florida Department of Environmental Regulation, 3319 Maquire Boulevard, Orlando, FL 32803; (407) 894-7555.

■ ARKANSAS

Arkansas addressed the specific problem of unattainable dissolved oxygen standards by restructuring its water quality program to include criteria based on natural dissolved oxygen levels. These biological criteria allowed Arkansas to reclassify streams to use designations that would protect the existing fish communities observed in reference streams within the same ecoregion.

Introduction

In 1982, the Water Division of Arkansas' Department of Pollution Control and Ecology began a five-year project to evaluate the aquatic ecoregions concept as a basis for reevaluating stream classifications. The State examined the physical, chemical, and biological characteristics of carefully selected streams in the six Arkansas ecoregions and subsequently employed ecoregion data to develop use attainability analyses.

The motivation for undertaking the Arkansas ecoregion program was the knowledge that many of the State's cleanest streams did not meet national water quality standards—not because of pollution but because of naturally occurring physical and chemical conditions. Rather than enforce inappropriate standards, State officials undertook an ambitious program to assess water quality and ecological conditions in representative least disturbed streams. These least disturbed streams were used as reference streams to refine use classifications and associated water quality criteria for similar streams and rivers around the State.

The Arkansas ecoregion program provides a sound basis for reclassifying streams where existing criteria and standards were either too stringent or too lenient. Arkansas has demon- strated the usefulness of the ecoregional approach for developing and evaluating water quality standards, particularly those concerned with fish community use designations and dissolved oxygen criteria (Ark. Dep. Pollut. Control Ecol. 1988; Rohm et al. 1987).

History

In Arkansas, the biological criteria effort began more than 10 years ago. During the late 1970s, the section 208-funded State Policy Advisory Committee devoted much discussion and effort to identifying solutions to water quality problems, which resulted in a proposed reclassification of Arkansas' streams according to hydrological types. The public comment during water quality program review was generally favorable toward the document, but further refinement was recommended. The committee agreed and encouraged the staff to continue working on the concept. In 1981, a National Science Foundation Grant was administered through the governor's office to convene engineers and scientists within the State to recommend directions for water quality programs. This State Ecological Congress recommended designating reference streams.

The development of biological criteria in Arkansas was closely related to several other aspects of the State water quality program. With the passage of Public Law 92-500, additional funds were provided for municipal wastewater treatment systems. Earlier, the wasteload allocations of the 303e basin plans had developed effluent limits for all dischargers. For the large rivers adjacent to metropolitan areas, secondary wastewater treatment was good enough to meet the five parts per million, dissolved oxygen water quality standards. However, the majority of smaller towns were located on small headwater streams that never reached this level during low-flow periods—even in pristine conditions. The 303e wasteload allocation process had determined that these small towns had to meet effluent limits that were often stringent and cost prohibitive. Arkansas determined that the water quality standard driving this process needed revision.

As this problem was addressed and the ecoregion concept was being developed, a new source of funding became available. Section 205j of the Clean Water Act set aside 1 percent of the section 201 Facility Grants monies to be used in water quality planning and management activities. This 1 percent set-aside for Arkansas averaged approximately $120,000 per year over the life of the Ecoregion Project, with approximately 14 percent going toward boats, motors, computers, generators, and other equipment. Over a three-year period, data were obtained from intensive field investigations of 37 reference streams during both the low-flow, high-temperature season and the higher flow and cooler temperatures of spring (Rohm et al. 1987). Information was obtained at an approximate cost of $360,000 to satisfy the primary goals of the project, which were to:

- Provide baseline data from waterbodies with the least amount of point source and nonpoint source disturbance,
- Complete a characterization of the streams within each ecoregion,
- Develop a classification of streams based on in-stream uses,
- Provide a reference gauge to evaluate monitoring data, abatement activities, and perturbations in other streams, and
- Provide a sound basis for development of realistic water quality standards and beneficial uses within ecoregions.

The ultimate result of this long-term effort was the specific identification of the biological community to be protected and a methodology to ensure its protection. Arkansas has now implemented water quality standards specific to sites and locations that are both higher and lower than the *Red Book* dissolved oxygen criteria. This has allowed small towns to begin building treatment plants that will attain effluent limits appropriate for the new water quality standards.

Discussion

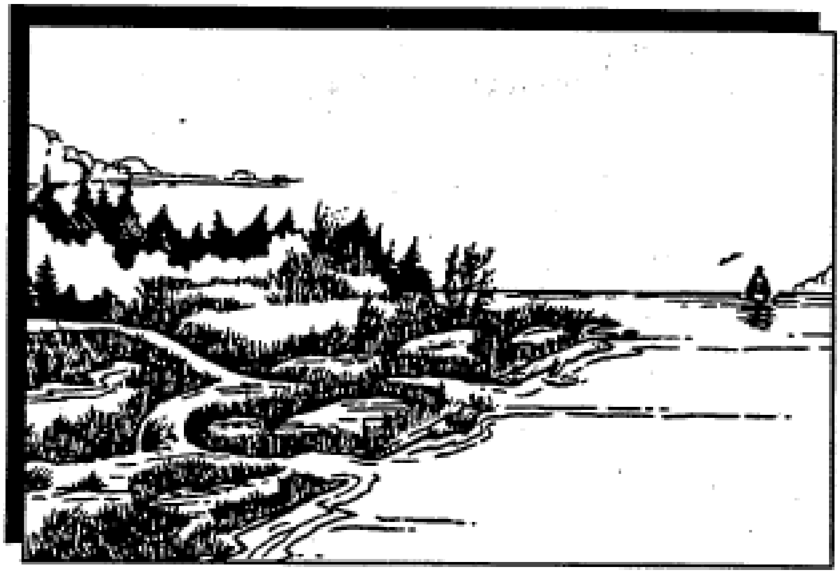
While it is impossible to accurately account for the full range of resources used during those efforts, Arkansas' final solution to the inapplicability of the dissolved oxygen-water quality standard was the Ecoregion Project, which was funded with $360,000 of 205j money. Approximately 10 to 15 people were involved in the project, and all had numerous other responsibilities.

The Ecoregion Project process formally started in 1983 and ended in 1988. The first major obstacle was overcome with the procurement of 205j monies. Although the State was convinced that this project was needed, equipment and personnel had to be scheduled so that other program responsibilities could be met during this project.

After the project was initiated, many indirect benefits to the water quality program became apparent. For the first time in Arkansas, good baseline information (physical, chemical, and biological) was available for specific ecoregions, revealing that each region was distinctly different. The staff soon realized that if these findings were ultimately to be incorporated into the water quality standards, the public would have to be continually educated. Therefore, presentations were made to a wide range of audiences, including water user groups, conservation groups, municipal leagues, colleges, and Lions Clubs. Perhaps for this reason, the project was a success and, in 1988, one of the most extensive changes to the Arkansas Water Quality Standards was implemented with very little opposition from industrial, municipal, or conservation organizations.

Initially, EPA's Environmental Research Laboratory in Corvallis, Oregon, laid out what they called "good, better, and best" approaches to the Ecoregion Project. As it turned out, Arkansas had only enough money and people to do something slightly less than the "good" project. Although money and staff remain a constraint, in retrospect the State would have liked to have invested greater resources and to have done the "better" project. They also would have added metals to their chemical parameter list (for measurements in water, sediment, and fish tissue) so that this background information would now be available. For further information, contact John Giese, Arkansas Department of Pollution Control and Ecology, 8001 National Drive, Little Rock, AR 72209; (501) 562-7444.

Chapter Four



Case Summaries of Biological Criteria in Seven States

Seven States are currently developing biological criteria as part of their water quality standards program. Texas, Connecticut, Vermont, New York, and Nebraska are developing reference conditions and qualitative assessment methods to support narrative biological criteria in the standards; Delaware and Minnesota are in the early stages of developing biological criteria programs.

■ TEXAS

The Texas Surface Water Quality Standards provide the framework that the Texas Water Commission uses to protect water resources. The standards recognize the geologic and hydrologic diversity of the State by dividing major rivers, streams, reservoirs, estuaries, and bays into classified segments. They contain narrative biological criteria that describe aquatic life attributes (species richness and composition, diversity, trophic structure, and abundance) on a sliding scale from limited to exceptional.

Segment-specific uses such as aquatic life, contact or noncontact recreation, oyster waters, public water supply, aquifer protection, industrial water supply, and navigation may be assigned by the Texas Water Commission. Narrative and quantitative numerical criteria are derived to ensure protection for some of the uses. One of four levels of aquatic life use (exceptional, high, intermediate, limited) is assigned to each classified segment.

Minor waterbodies are grouped as unclassified waters and provided protection under the general criteria of Texas' water quality standards. A contact recreational use and one of the four aquatic life uses are assigned to perennial unclassified waterbodies by the commission at the time of administrative or regulatory action. Appropriate 24-hour and absolute minimum dissolved oxygen criteria are assigned to classified and unclassified waters to protect aquatic life. The four levels of aquatic life use accurately describe Texas waters and are sufficiently broad and flexible to encompass the range of expected conditions.

Assignment of an appropriate aquatic life use to a waterbody is primarily driven by an assessment of biotic integrity. Preliminary quantitative biological criteria, based on six measures of the benthic macroinvertebrate community and four measures of the fish community, were developed by Twidwell and Davis (1989). The ranges for the criteria were derived from the published literature and the professional judgment of investigators with 30 years of combined experience performing biological assessments of Texas streams. Biological data collected in the field, usually during summer, are compared to the narrative and quantitative criteria to provide the basis for aquatic life use assignment. Benthic macroinvertebrate (macro- benthos) and/or fish communities may be used, although emphasis is placed on the collection of both groups because of their differing sensitivities.

During the summer of 1987, the Texas Water Commission conducted a pilot study on six unclassified freshwater streams located in different areas of the State. The study was conducted to assess the applicability of the preliminary biological criteria and determine if unclassified streams should be assigned aquatic life use designations. The study revealed that most of the streams possessed physical habitat heterogeneity that enhanced the development of communities of diverse aquatic fauna. The occurrence of high biotic integrity in small streams during adverse summertime conditions was particularly noteworthy. In response to these findings, the commission changed the manner in which it assigned aquatic life uses to unclassified waterbodies during the 1987 triennial revision of the standards.

The biological data collected during the study also suggested that differences among waterbodies sampled in different areas of the State were spatially related. In the summer of 1988, the commission initiated a three-year study in cooperation with the Texas Parks and Wildlife Department to determine if the regional patterns would correspond to the ecoregions of Texas mapped by Omernik and Gallant (1987). Waterbody characterizations have been conducted at 72 carefully selected reference sites located in Texas' 11 different ecoregions.

The resulting physical, chemical, and biological (macrobenthos and fish) data are being assessed to indicate the water quality, levels of habitat complexity, and biotic integrity that can be naturally attained within each region, determine to what extent Texas ecoregions have distinctive fish and macrobenthic assemblages, and regionally calibrate the existing quantitative biological criteria. The eventual goal of these studies is to develop water quality standards that are individually tailored to the different ecoregions of the State. For further information, contact Stephen Twidwell and Jack Davis, Water Quality Division, Texas Water Commission, P.O. Box 13087, Cap. Sta., Austin, TX 78711; (512) 463-8475; or Roy Keinsasser and Gordon Linam, Resource Protection, Texas Parks and Wildlife, P.O. Box 947, San Marcos, TX 78667; (512) 353-3474.

■ CONNECTICUT

Narrative biological criteria for benthic macroinvertebrates (lotic waters) were proposed in draft form by Connecticut in 1985 and adopted in its water quality standards in 1987.

Connecticut has a biological monitoring database that goes back to 1973 and contains semiquantitative macroinvertebrate data on approximately 75 sites. Bioassessments based on these data originally relied on the evaluation of community structure parameters (taxa richness, dominant taxa, sensitive taxa or EPT—insect orders Ephemoptera, Plecoptera, and Tricop- tera—average diversity, abundance) and the Hilsenhoff Biotic Index. EPA Rapid Bioassessment Protocol III (Plafkin et al. 1989) was incorporated into the program in 1987 and adopted as the primary assessment method in 1989.

Connecticut routinely uses the bioassessment process to evaluate spill incidents, point source impacts, and the effectiveness of waste treatment installations. Recent 305(b) assessments for the years 1988 and 1990 have also incorporated biomonitoring information as a measure of use attainment. In 1989, biological monitoring data were employed to assess use attainment and impairment at 22 sites in support of numeric criteria development for copper and zinc based on ambient water quality monitoring.

Also in 1989, Connecticut initiated development of a numeric component to complement existing narrative biological criteria. A general description of the intended procedure is outlined below:

- Initial work involved reviewing existing biological, physical, and chemical data to identify prospective ecoregional reference sites. (Connecticut is a relatively small State, existing entirely within one ecoregion.)
- The existing database contains seven reference sites. Current efforts are directed at expanding this database and characterizing variations that result from sampling methods and temporal and spatial effects.
- Connecticut's goal is to develop a methodology using Rapid Bioassessment Protocol III (for benthos) or selected component metrics that can describe existing narrative criteria for the various water quality classes and provide a standard means to evaluate waterbodies relative to these criteria.

For further information, contact Ernest Pizzuto or Guy Hoffman, Connecticut Department of Environmental Protection, Water Management Bureau, 122 Washington Street, Hartford, CT 06106; (203) 566-2588.

■ VERMONT

Vermont uses biological criteria from in-stream data to determine if two different types of biological standards are being met. These standards are the following narratives, which are found in the State's water quality standards:

- **No Significant Alteration of the Aquatic Biota (NSAAB).** This standard is applied to all nonpoint discharges through a permit process that uses compliance monitoring data generated by the discharger. The NSAAB criterion is designed to detect community-level changes that result from slight (benign) enrichment.
- **No Undue Adverse Effect (NUAE).** This standard is Vermont's classification standard. At the present time, a single biological standard will probably be applied to both Class B and C waters. Class C water will be set apart from Class B only because of human health concerns—as a bacterial standard.

Both of these biological standards are narrative statements within the State's water quality standards. The Vermont Department of Environmental Conservation has developed a set of administrative rules to define the NSAAB narrative standard. The department is negotiating with the State's Water Resources Board to develop a similar set of administrative rules to define NUAE. It believes that, by using the administrative rules process to define biological standards for a class of water, it can exercise the flexibility needed to sample and describe the different communities found in different ecotypes (lakes, rivers, and small streams).

For the past four years, the Water Quality Division has been developing both a macroinvertebrate and fish database to use in establishing biocriteria for streams; the program is called the Ambient Biomonitoring Network. The division experimented with sampling and analysis methodologies several years before it felt confident that it could both measure the biological impacts and be cost and time efficient.

The Water Quality Division has drafted preliminary biocriteria for small streams in Vermont using both macroinvertebrate and fish community metrics. The fish community evaluation is based on a modified Index of Biotic Integrity (IBI) for Vermont streams. Two regions have been identified for fish communities, based on elevation. The macroinvertebrate community is evaluated using several biological metrics in series. Presently, these metrics are mean taxa richness, EPT richness, presence/absence of EPT orders, Hilsenhoff-Vermont modified-biotic index, and species dominance. At paired sites (above and below discharges), the Pinkham-Pearson similarity index and the difference in density between sites are also used to evaluate impairment to both the fish and macroinvertebrate communities. Functional group metrics are currently being evaluated for future use.

Vermont can evaluate two to four sites within one week, using one expert biologist and two technicians trained in taxonomy. Generally, the macroinvertebrate Ambient Biomonitoring Net- work trend monitoring is done yearly; samples are collected from 40 to 50 sites within three to four weeks (usually during September or October), and data are worked up during the winter months. In this way, many sites can be monitored over the long term, and a large database can be generated for a specific season. This routine also frees staff for more intensive, site-specific evaluations and to spend time in the field conducting fish surveys during the short summer.

The Ambient Biomonitoring Network program (used to define NUAE) and the Compliance Monitoring Program (NSAAB) have helped document biological improvements after treatment plant upgrades and have identified extensively impaired stream communities. This work focuses water quality management activities on specific problems that need to be addressed from a biological standpoint.

Most of the information generated by the biological monitoring program is reported in memo form to appropriate department chiefs. An annual biological condition report is being developed to make the information more accessible to other governmental bodies and public groups. For further information, contact Steve Fiske or Rich Langdon, Department of Environmental Conservation Laboratory, R.A. LaRosa Laboratory, 103 South Main Street, Waterbury, VT 05676; (802) 244-4520.

■ NEW YORK

The State of New York has developed a set of biological impairment criteria based on five measures of the benthic macroinvertebrate community. These criteria are designed to measure significant biological impairment of the stream biota as determined by site-specific comparisons between locations upstream and downstream of given discharges. Using the paired-site comparison method (Green, 1979), significant biological impairment in discharge sites can be determined relative to an upstream control, or, if none is available, relative to a comparable nearby stream.

Methods equivalent to a replicated EPA Rapid Bioassessment Protocol-3 (Plafkin et al. 1989) are used to determine five macroinvertebrate community parameters:

- Species richness,
- EPT value (number of species of cleanwater insect orders),
- Hilsenhoff Biotic Index (average species tolerance),
- Species dominance (percentage contribution of dominant species), and
- Percent Model Affinity (similarity to a model community).

Once habitat and substrate evaluations have determined that the paired sites are comparable, replicated values are compared between the two sites to determine if the criterion is exceeded for any parameter. Any criterion violation shown to be statistically significant with a t-test giving a value of $p=0.05$ is considered to be a biological impairment.

New York's biological impairment criteria have been drawn from 214 data sets collected on 27 streams between 1983 and 1987. Of the sites designated as having significant biological impairment based on these criteria, 68 percent had known problems, 26 percent were probable new detections, and 6 percent were questionable. This demonstrates the usefulness of the approach for problem detection, problem assessment, and trend monitoring. The Stream Biomonitoring Unit of the New York State Department of Environmental Conservation recently completed a two-year program of field testing and modifying the proposed criteria. For further information, contact Robert Bode, Stream Biomonitoring Unit, Bureau of Monitoring and Assessment, Division of Water, Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233-3503; (518) 432-2624.

■ NEBRASKA

Biological criteria in Nebraska's water quality standards are narrative and directed at preventing human activities that would significantly impact or displace identified key species. The key species listed in the standards are endangered, threatened, sensitive, and recreationally important aquatic species. Nebraska has a large biological monitoring program and currently uses biological indices to evaluate the condition of aquatic life. In Nebraska 305(b) assessments, both the Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) are used with reference sites. Nebraska's ambient monitoring stresses evaluation of both the fish and macroinvertebrate communities but, because of the pattern of barriers and seasonal drying of waterbodies in the State, macroinvertebrate measures may eventually prove more informative.

Nebraska is currently expanding its evaluation approach by incorporating ecoregion- and resource-specific factors. Regional ICI and IBI values that indicate unimpaired conditions for various stream types are being developed. Nebraska hopes that this will lead to the establishment of numeric biological criteria in the future.

Nebraska has determined that enforcing water quality on the standards alone is difficult. Therefore, the Department of Environmental Control uses its standards and aquatic life evaluations to write permits. For example, although there is a "free of junk" provision in the water quality standards, it is easier in Nebraska to establish the legal basis for a violation of the 404 permit to fill a wetland. Therefore, informal biological criteria applied to the ambient monitoring program in Nebraska are used to identify problem areas for enforcement by permit or for mitigation through increased nonpoint prevention efforts.

Site-specific studies employing a modified EPA Rapid Bioassessment Protocol are another tool increasingly used by the department to identify in-stream problems from point source discharges. Parameters identified include EPT richness and Chironomidae exuvia. Problems identified by these procedures range from the need for additional treatment capabilities and water quality-based permits to poor operation and maintenance of facilities. For further information, contact John Bender, Department of Environ- mental Control, P.O. Box 98922, State House Station, Lincoln, NE 68509; (402) 471-4700.

■ DELAWARE

Delaware began the early stages of a biological criteria development program in 1988. The project was initiated for several reasons: EPA priorities for the water quality standards program; requests from EPA Headquarters to include biological criteria development in the nonpoint source management program; and staff knowledge of the potential advantages of biological criteria for integrated assessments of water quality conditions.

To date, Delaware has identified possible reference sites for ecoregions and established control and effect sites in nonpoint source demonstration project subbasins. Three sets of 19 samples are planned for the early stages of the project, including work in the spring, summer, and fall. Delaware is using the rapid bioassessment protocols developed by EPA (Plafkin et al. 1989) and is attempting to modify these protocols for coastal plain and estuarine systems (dominant stream types in Delaware).

A database of literature was gathered and assessed before Delaware selected approaches. All involved staff were trained in the protocols. Delaware has approximately two full-time equivalents committed to the project, divided among field biologists, an office scientist, and program oversight and management.

Partial funding for the work has been obtained from the State's nonpoint source management program grant. The State's near-term goals are to use the rapid bioassessment protocols to assess impacts of nonpoint source pollution on small streams and develop an ecoregional reference site database.

In the long term, Delaware hopes to develop narrative and numeric criteria, possibly in line with EPA's goals of the second and third triennium (1992 and 1995). For further information, contact John Maxted, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control, 89 Kings Highway, P.O. Box 1401, Dover, DE 19903; (302) 736-4590.

■ MINNESOTA

The Minnesota Pollution Control Agency is investigating the application of biological criteria for designating aquatic life use designation and water resource assessment. The initial focus of this investigation is to develop attainable regional goals in terms of fish community characteristics using the Index of Biotic Integrity (IBI). IBI community metrics will have to be modified in Minnesota's various regions because of significant geographic variations in fish assemblages. Three continental drainages and the transition zone between the eastern woodlands and western prairies all exist within Minnesota's borders.

The Pollution Control Agency will determine metric composition and expected metric values by using historical information and data collected at reference or at least impacted sites throughout the State. The historical information is available from stream surveys conducted by the University of Minnesota and the Minnesota Department of Natural Resources .

The Minnesota River watershed is the first area where the IBI is being applied. During the summer of 1990, staff from the State's Department of Natural Resources and the Pollution Control Agency sampled 45 reference sites throughout the watershed, including headwater, midsize, and large river segments. Habitat evaluations were conducted. Flow and limited water chemistry information was also obtained at each site, and data from over 500 collections were reviewed. Metric modifications and expected metric ratings will be completed early in 1991. The IBI developed will be used during the summer to identify impacted areas in a major river system within the Minnesota River watershed.

In the future, Minnesota wants to develop the IBI for the rest of the State, add a macro- invertebrate component to the stream assessment program, and develop biological criteria for wetlands, primarily by using macroinvertebrates. Presently, there is one full-time person working on the stream project with some additional contract staff assistance from Minnesota's Department of Natural Resources. An additional half-time person will be hired for the wetlands project if funding is secured. For further information, contact Patricia Bailey or Judy Helgen, Minnesota Pollution Control Agency, Division of Water Quality, 520 LaFayette Road North, St. Paul, MN 55155; (612) 296-8878.

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*U.S. GOVERNMENT PRINTING OFFICE: 1991—526-392/40828